Journal
of
The Franklin Institute

EDITOR, HENRY BUTLER ALLEN, MET.E., D.Sc.
ASSISTANT EDITOR, JOHN FRAZER, PH.D.

Associate Editors:

WILDER D. BANCROFT, PH.D. — A. S. EVE, F.R.S. — HENRY C. SHERMAN, SC.D.
C. B. BAZZONI, PH.D. — PAUL D. FOOTE, PH.D. — W. F. G. SWANN, D.SC.
E. G. COKER, F.R.S. — W. J. HUMPHREYS, PH.D. — HUGH S. TAYLOR, D.SC.
ARTHUR L. DAY, SC.D. — C. E. K. MEES, D.SC. — A. F. ZAHM, PH.D.
R. EKSERGIAN, PH.D. — WILLIAM B. MELDRUM, PH.D. — JOHN ZELENY, PH.D.

Committee on Publications:

G. H. CLAMER, CHAIRMAN — LIONEL F. LEVY — HIRAM S. LUKENS
RICHARD HOWSON — MALCOLM LLOYD, JR. — RICHARD H. OPPERMAN
C. L. JORDAN — WINTHROP R. WRIGHT

Vol. 237 **APRIL, 1944** **No. 4**

CONTENTS

Multiple Purpose Rivers ..... MORRIS LLEWELLYN COOKE 251

Science and the Scheme of Things ..... WILLIS R. WHITNEY 265

Meteorology in The Franklin Institute ..... ARMAND N. SPITZ 271

A Proposed Spectral Sensitivity Index to Describe Photographic Emulsions. D. R. WHITE 289

Zeros of Bessel Functions ..... D. B. SMITH, L. M. RODGERS, AND E. H. TRAUB 301

Notes from the National Bureau of Standards 305

The Franklin Institute Notes 311

Notes from the Biochemical Research Foundation 315

An Apparatus for Grinding Small Samples of Brain Tissue. H. M. TERRILL AND D. W. MCKINSTRY

Book Reviews 317

Publications Received 319

Current Topics 288, 300, 304, 320

Published by

THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA
Prince and Lemon Streets, Lancaster, Penna., and
Benjamin Franklin Parkway at Twentieth St., Philadelphia, Penna.

SIX DOLLARS PER YEAR (Foreign Postage Additional) **SINGLE NUMBERS, SIXTY CENTS**

Indexes to the semi-annual volumes of the JOURNAL are published with the June and December numbers. The contents are also indexed in *The Industrial Arts Index*.

Ready this month

BLAKISTON'S

BLAKISTON'S NEW GOLD MEDAL

BLAKISTON'S NEW GOLD MEDAL

BLAKISTON'S NEW GOLD MEDAL

Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 237 APRIL, 1944 No. 4

MULTIPLE PURPOSE RIVERS.

Decisive Factors in National and International Rehabilitation.

BY

MORRIS LLEWELLYN COOKE,

Consulting Engineer, Philadelphia.

From the earliest days of the race, the rivers of the world have been used by man primarily for transportation. Here and there, water wheels have been utilized to pump water for irrigation and to do other useful work. In the early days of the United States, water-driven grist mills were common, and a few are still operating. In specially favored spots, rivers have given people an essential part of their food supply. The Nile, with its periodic overflow of rich sediment, has kept this valley of Egypt productive across the years. Many rivers draining a populated territory afford the main source of potable water and unfortunately are frequently used to carry off sewage.

But with the development of our ability to create electricity by converting the energy of falling water, new vistas have been opened up in river and river valley development. Rivers with an adequate fall, a desirable configuration of their shore lines, and the proper lay to the adjoining land areas—the features which make hydro-electrical development possible—have become, potentially, multiple-purpose agencies of tremendous social significance. In some instances, these potentialities are on a scale which staggers the imagination.

Electricity was first developed on a commercial scale in the early Eighties by burning coal under boilers, thereby generating the steam which furnished motive power for the electricity-producing mechanisms. Within ten years thereafter came the development of long-distance transmission of electricity. This made it economically feasible to build dams at favorable sites on our rivers.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

These dams originally were single purpose structures—built to develop power and sometimes located where power development was the only purpose possible. More recently, multiple-purpose dams have become rather the rule. Power and flood control dams have been built on the upper reaches of the Allegheny in western Pennsylvania. Grand Coulee generates power on an inspiring scale, combines with it some flood control, and, in prospect, there is a farflung irrigation scheme. The dam at Fort Peck in eastern Montana was designed to reduce floods on the upper Missouri River and as an aid to transportation. It does create power but as a quite secondary purpose. Bonneville in Oregon combines power and important transportation facilities. On the other hand, our own Conowingo, because it is located just above the estuary of the Susquehanna, is essentially a power project.

Early hydraulic power installations were definitely limited in size. Further, the difficulty in taking the power any great distance from the site of the installation limited its usefulness. However, when electricity, as contrasted with mechanical power, became the product, the problem of transmission all but disappeared. With the larger hydro-electric installations, the feasible transmission distance may run into hundreds of miles. Thus through the building of dams there is made available vast quantities of power ready to be distributed far and wide. There are thus opened up for each river region many new possibilities including:

1. Readjustment of the population pattern to fit the agricultural-industrial environment,
2. Planned agricultural and industrial developments,
3. Adequate and pure water supply,
4. Widespread irrigation and drainage works,
5. Controlled sedimentation—controlled in the sense of
   (*a*) keeping baneful sediment (pollution) out of the stream,
   (*b*) permitting regulated deposition of sediment that will be beneficial to agricultural land, and
   (*c*) preventing the filling of reservoirs and channels with silt,[1]
6. An improved and balanced agriculture, including soil conservation, flood control,[2] and recreation, together with vastly improved transportation facilities.

All this and more can be accomplished on a coördinated basis, as contrasted with the isolated, more or less accidental, and detached practices heretofore the rule.

---

[1] Brown, Carl B., "The Control of Reservoir Silting," Miscellaneous Pub. No. 521, Soil Conservation Service, U. S. Dept. of Agr., 1943.

[2] Bennett, H. H., "Headwaters Control and Use," Proc., Upstream Engineering Conference, Washington, 1936.

Bennett, H. H., "Conservation Farming Practices and Flood Control." Miscellaneous Pub. No. 253, Soil Conservation Service, U. S. Dept. of Agr., 1936.

But—and here is a very significant point—in such a development the center of interest passes from the dam to the river itself and to the watershed which it drains. From a social standpoint the river itself becomes a vastly important, multiple-purpose agency which, as will be seen, must be nurtured in manifold and unaccustomed ways while the dam becomes simply an important servitor of the river. In fact, it may be said that our present concentration on the dam and the beneficent power it creates has blurred the picture and kept us from realizing all that is involved in total river use as affecting regional development.

The picture is further blurred because of long-existing management practices in government. In Nature the functions of river and land are one. Under generally prevailing administrative practice, however, they are divided up among specialized agencies, separate in policy and direction. The inter-relation of valley and river and the coördinate character of the river's various potential uses should be reflected in a corresponding unity of managerial direction—a single coördinating agency, not several separate ones.[3] The relation of such a semiautonomous agency to, and its servicing by, the Federal government is among the unsolved problems of public administration.

Now that we Americans are coming to realize that our own welfare is affected at least in some measure by the welfare of other parts of the world, the study of river development is likely to assume an important place in international planning and coöperation. But the same physical facts and social values of course have validity right here at home in Pennsylvania and must be recognized and dealt with as fateful factors in the future of the Commonwealth.

The international implications of river valley development were brought home to me recently in connection with a study of the San Francisco River in Brazil, undertaken on the suggestion of President Getulio Vargas. Here is a grand waterway—little known to outsiders—with its headwaters 1,700 miles from the sea, draining a wide valley of untold potentialities, capable of supporting many millions of people, which lies all but socially inert for lack of a plan. As one competent observer has put it: "The San Francisco is comparable with the greatest rivers of the world. Its valley offers irrigable acreage as large as that of cultivated Egypt. Its annual inundation, like that of the Nile—that other great northward flowing river of the five continents—covers its banks with rich alluvial silt each year, to a width of from ten to twenty miles, over a course of more than one thousand miles. A Ludwig may some day write the story of its frustration."

So, in the Balkans, the Middle East, Russia, India, and China, civilized man is going to be forced to cope with both the demands and

[3] Hansen, Alvin H., and Perloff, Harvey S., "Regional Resource Development," National Planning Assn. Pamphlet No. 16, Oct. 1942.

the possibilities of some of the world's great rivers if the dreadful poverty and low scale of living for the mass of mankind is to be ameliorated and ultimately blotted out. We must either conquer poverty or it will surely submerge us. In the nation, and throughout the world, we must get away as far as may be from the idea that every river development is different. They are different, of course, as to some of the engineering details but not as to their broad social, economic, political and technical implications.

Rivers flowing through undeveloped areas such as are to be found in the interior of Brazil and in the Balkans are especially inviting prospects for such planning, because no works of any kind have been built such as could preclude the best utilization of all possibilities. This is not the case with many of the rivers flowing through the more built-up sections of the United States. Even low head dams are uneconomic when they flood out urban or even thinly developed areas. Low head dams on the Delaware above Trenton or high head dams on the upper Mississippi, for instance, are impossible without incurring excessive damage.

In river, river valley, and watershed development the largest possible electrical development consistent with the lowest cost is the first magic wand which under modern conditions makes two or more blades of grass grow where one grew before—interpreting the grass to signify all those things which make a nation truly great through constantly raising the standards of living for all the people, and at the same time making possible the greatest freedom of action for the individual, consistent with the highest welfare of the community. Judged by this standard, the main channel of the Amazon, one of the great rivers of the world, draining an area as large as the United States and lying in five different countries, can hardly be considered a multiple-purpose stream, because not only is there no opportunity for electrical development along the 3,000 miles of its majestic course from west to east, but there are no proven coal deposits in the region.

We in the United States have been the first among the nations of the world to explore in comprehensive fashion the possibilities of multiple-purpose river development. We have demonstrated this for all the world to see in our experiments with the Tennessee River watershed, which includes parts of five of the states of the Union. Beginning in the early days of its discussion in Congress as a distinctly power project, the scope and purpose and vision back of the plans have been constantly widened until people from all parts of the world come in increasing numbers to study what has already been done, as well as what is planned for the future. With explicit responsibility for the unified development of all the multi-purpose functions of the river lodged in a single agency and acting under wide powers afforded by far-sighted legislative grants, the Tennessee Valley Authority [4] started to work in 1933 on a region tra-

[4] See "TVA: Democracy on the March," by David E. Lilienthal, Harpers, 1944.

versed by a wandering, unruly river, subject to dangerous floods, and with a badly eroded soil that yielded poor returns to the farmer. Here was a region so poor that the taxes could not support a good school system with a resulting high rate of illiteracy. The TVA has developed the waterpower on that river through a series of dams which have translated the falling water into the maximum volume of electric energy consistent with a reasonable control of floods. Those kilowatt-hours, in turn, have been sent into the farm houses to make the work of the women lighter; sent to Muscle Shoals to create fertilizer for use on thinning land to make men's work more productive; and sent to the villages, towns and cities to operate industries for the employment of the extra sons and daughters of the farmers.

Of course there are other rivers in our country and in many foreign countries which have been given beneficent development. Switzerland is perhaps the country best known for having achieved a high degree of industrialization without at the same time creating large factory centers with their usual complements of industrial slums. The principal industrial developments have taken place in villages and small towns located in the Midlands a belt of lakes, valleys and hill country lying in the glacial trough between the Jura Mountains and the foothills of the Alps, averaging about 30 miles in width and extending for 150 miles from Lake Leman to the Sea of Constance. Although not particularly favored by nature as to richness of soil or other resources, this area has nevertheless become one of the most prosperous and densely populated in Europe. Originally heavily forested and lined with rivers, lakes, glacial moraines and swamps, the area has been improved by man until it resembles one huge park. The transformation has taken place through the utilization of an extensive system of small but rapidly-flowing rivers for hydro-electric developments. The clearing and draining of the valleys have left a neat pattern of meadow-lands with orchards and vineyards on the slopes and crowns of trees on the hilltop which give an impression of order almost too picturesque to be real.

Rothrist on the Aar (Fig. 1), population 2,500, is typical. Until the late 19th century the villagers were peasant farmers and foresters, and very poor. About 100 years ago the village authorities cut down and sold wood in order to charter a boat to take the town poor, and other excess population wishing to emigrate, to the United States. The present population seems to have achieved a way of life which compares favorably with that of those who emigrated in early days and particularly with those who may have gone into the industrial cities of other countries.

While plenty of cheap power is a master key in opening up a river valley to its best development, even the widest distribution and use of electricity, in the absence of other steps, will not necessarily develop the potentialities of the best endowed valley, or even guarantee its continued

well-being. First of all, the water in rivers must be safeguarded as to volume and quality and regularity of flow. This implies, among other

FIG. 1. Rothrist in Switzerland.

A village typical of many others in the industrialized Aar Valley which has effected a greatly improved standard of life through river development.

considerations, regard for the route by which the rainfall reaches the river. We can see a stream being fed by other streams which flow into

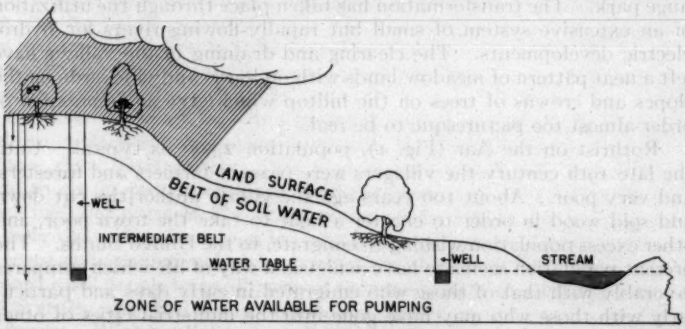


FIG. 2. Subsurface water storage.

it, some of them in dry as well as in flood seasons. But we do not see the much more healthful manner in which streams are constantly fed and their purity and their flow maintained from underground sources

(Fig. 2). This normal phenomenon of nature is facilitated by the use, throughout the cultivated areas of the watershed, of those soil conservation practices [5] such as contour plowing, strip farming and terracing—through which the maximum percentage of the rain that falls penetrates the surface (Fig. 3), and thus helps to build up valuable underground reserves of water—water in the soil for nurturing growing crops, and water at lower levels for irrigation, industrial, and other uses, by pumping.[6] The marked lowering in recent years of the water-table—the normal level at which sub-surface waters stand—over large parts of the United States must be looked upon as catastrophic. In Ohio, for in-

FIG. 3. Conservation-treated farm in the hill country of South Carolina.

stance, the drop has already been such as to threaten the further growth of important industrial plants. We must learn to hold the raindrop where it falls (Fig. 4).

Assuming that the physical steps mentioned above have been taken to control soil erosion, soil technicians foresee fundamental developments in the direction of the conservation and increased use of soil minerals.

Constantly recurring floods, carrying with them increasing loads of silt and the other materials of which soil is composed, scour the bottoms

[5] Cooke, Morris Llewellyn, "Rebuilding America's Primary Wealth—The Soil," JOURNAL OF FRANKLIN INSTITUTE. Philadelphia, October 1943.

[6] Rohwer, C., "Putting Down and Developing Wells for Irrigation," Circular 546, Soil Conservation Service, U. S. Dept. of Agr., 1940.

of streams of the vegetable and insect life upon which fish life depends. Further, there are few streams left bordered with ferns and mosses in most parts of our country. These were the rule in nearly all parts of the United States seventy-five years ago and are still pictured in books for children. The fact that the present generation does not miss them makes the loss all the more depressing to those who know. In the matter of the quality of water, one can see how far we have departed from the "crystal clear" pools of the poets when it has to be admitted

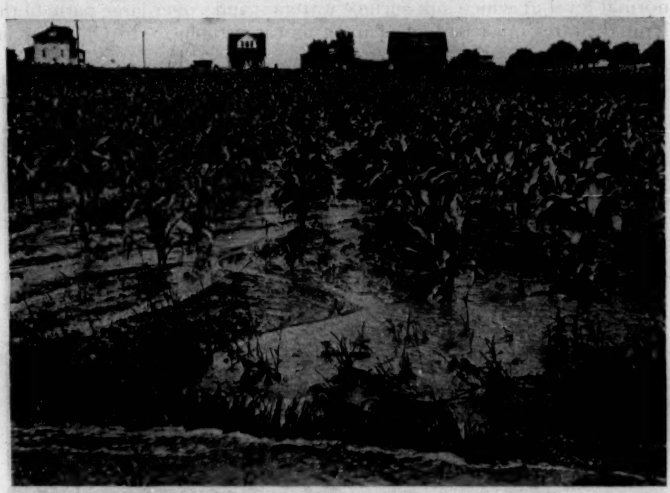


FIG. 4. Waste of soil and water in a corn field.

Located in the hill section of Maryland, as the result of the wasteful practice of running corn rows up and down the slope rather than across the slope on the level, or contour. Water is wasted, floods created and land is damaged. The scene might well have been enacted in either Berks or Bucks counties in Pennsylvania.

that a considerable body of engineers look upon our rivers as designed to carry off sewage and industrial wastes.

River valley development presupposes reasonably correct land use. This is more readily effected, of course, in undeveloped areas such as constitute the greater part of Brazil than in our own country. W. C. Lowdermilk, who has just returned after a year's tour of duty with the Chungking Government, tells of a situation in the fairly densely populated Province of Szechwan where the occupations of the population will have to be quite generally changed to effect proper use of the land and bring about any considerable measure of well-being. Lands best

suited for growing of grass and timber are being cultivated for food products because the mountain people have no other way now of getting their food. Many of the desirable changes will depend upon the creation of cheap transportation to carry food from the lowlands, where it may be produced most efficiently, into the mountainous areas for the exchange of products for which those areas are best suited.

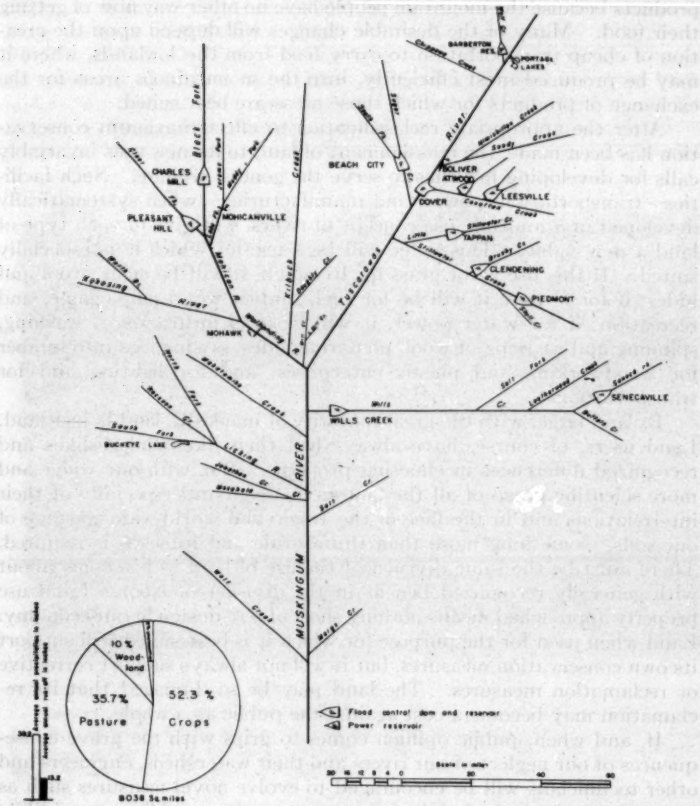
After the appropriate reclassification to effect maximum conservation has been made, the reassignment of land to its new uses invariably calls for developing facilities to serve the general welfare. Such facilities—transportation, power, and manufacturing—when systematically developed in a multiple use concept of rivers, will give to each type of land a new value. This value will be a use for which it is especially suited. If this use is for grass for livestock, it will be meat, wool and hides; if for forests, it will be for fuel, timber, wood pulp, game, and recreation; if for water power, it will be local industries of washing, spinning and weaving of wool, preparing hides, sawing logs into lumber for woodworking and plastic enterprises, and for lighting and for transportation.

By and large, with the great majority of mankind, land is just land. Land users, of course, have always had their likes and dislikes and recognized differences in choosing property. But with our wider and more scientific grasp of all the factors involved and especially of their interrelations and in the face of the tragic and world-wide wastage of our soils,[7] something more than thumb rule and hunches is required. There must be the same division of the use of land as has come about with generally recognized benefit in the division of labor. Land use properly approached means nothing short of a re-design in our economy. Land when used for the purpose for which it is best suited will support its own conservation measures, but it will not always support corrective or reclamation measures. The land may be so damaged that its reclamation may become a cost against the public as a whole.

If, and when, public opinion comes to grips with the grave consequences of our neglect of our rivers and their watersheds, engineers and other technicians will be encouraged to evolve novel measures such as some schematic method of depicting streams, thus enabling us to isolate the factors having real significance and to develop useful common denominators. Perhaps parallel lines with streams flowing to the right above and those flowing to the left below the main stream will not only provide a more compact picture than the scheme (Fig. 5) used by Jarvis [8] but also provide adequate opportunity for recording essential

[7] Bennett, H. H., *Annals of the Assoc. of American Geographers*, Vol. XXXIII, No. 4. Lancaster, Pa., Dec., 1943.

[8] "Supplementary Gleaning from the Field of Hydrology," by Clarence S. Jarvis. Privately printed, September 1943.



SCHEMATIC DRAWING OF MUSKINGUM RIVER SYSTEM

SHOWING LENGTHS AND RELATIVE POSITIONS OF STREAMS, DRAINAGE AREAS AND LAND USE, MAJOR REGULATING RESERVOIRS, AND BASIC HYDROLOGIC DATA.

FIG. 5. An Ohio watershed.

data. Our attitude toward rivers derives too largely from early association with our "geography book"—itself an outworn educational device.

Once a river and its valley are organized and placed on the firm ground of correct land use a thousand and one steps forward are generated more or less spontaneously. Take two examples out of TVA experience; first, the development under H. A. Morgan of triple superphosphate—a high-powered phosphatic fertilizer which has gained world-wide recognition; and, second, the adaptation by H. E. Kiefer to small farm practice of alfalfa and other hay drying consisting of throwing an electric switch and a few dampers once or twice a day in an inexpensive procedure which has come into use all over the country.

In view of our growing sense of interdependence—as between the urban, suburban, and rural, and as between those who have and those who have not so much, and as between the lettered and those whose education is a bit sketchy—those of us who live, for instance, in the long established economy of eastern Pennsylvania may well inquire as to the extent to which our noble streams—the Delaware, the Schuylkill, and the Susquehanna—have been given multiple purpose direction and the complex interests domiciled in their watersheds have been advanced thereby. We have built fairly large single purpose power dams at Safe Harbor, Holtwood and Conowingo on the Susquehanna and on the Waulenpaupack which feeds into the Delaware. These works simply amplify an electricity supply already safeguarded by our coal deposits. But no steps have been taken as yet to construct the recommended regulating works on the upper reaches of these streams which would give to each power dam "down stream" a more uniform output and tend to mitigate the floods which year by year become more menacing, and thus to give to these works something of a multiple purpose quality. A large single purpose dam has been built on the upper reaches of the Delaware in order to send its waters over 85 miles to the East to be used as a part of the potable water supply for New York City. In a sardonic sense, these Pennsylvania rivers have been given a multiple purpose character in that they are used as a convenient and supposedly inexpensive mechanism for carrying off sewage and industrial and mine wastes. Up to Trenton on the Delaware and up to Philadelphia on the Schuylkill—not a great distance—we have had a thought for transportation and done something about it through Federal appropriations and the good offices of the Army Engineers made possible thereby. But there multiple purpose seems to stop!

Without attempting at this time to describe in detail all that might be expected to grow out of giving far-reaching multiple purposes to the Delaware River, for instance, attention can be directed again to the common interests that both the citizens of Philadelphia and their neighbors in Bucks, Schuylkill and other nearby counties have in keeping silt out of the river. The city government in the not distant future

will discover that it can no longer bear the expense of removing the constantly increasing silt load and will, in all probability, be mistakenly led to go far afield for its water supply. The nearby farm people will belatedly, I am afraid, wake up to the fact that intrinsic farm values have drastically fallen due to soil wastage (Fig. 6). Especially in parts of New Jersey, not far distant from Philadelphia, the fertility of some agricultural areas has so depreciated that it hardly pays to farm them. Both food and feed consumed in Philadelphia and formerly grown in nearby Pennsylvania and New Jersey now reach us from Florida and

FIG. 6. Conservation of rainfall through contouring.

By this process water is stored in the reservoir of the soil for subsequent use by crops; and it is thus prevented from running rapidly off the land to wash away soil and augment floods.

Iowa. Only the prospect of some day selling out for building lots maintains the local rural real estate market.

The map (Fig. 7) outlining some of the sub-watersheds of the Delaware Valley breaks this problem down into its parts and points in the direction of local responsibilities. It would be sensible for city and country folk to join hands, and by giving the Delaware a multiple purpose character, put an end to these growing threats.

Over seventy-five years ago the great Shaler, of Harvard, expressed the view that it had not then been determined whether civilization was compatible with the maintenance of soil fertility. Were he living today his attitude would not likely be very different. We have learned a lot

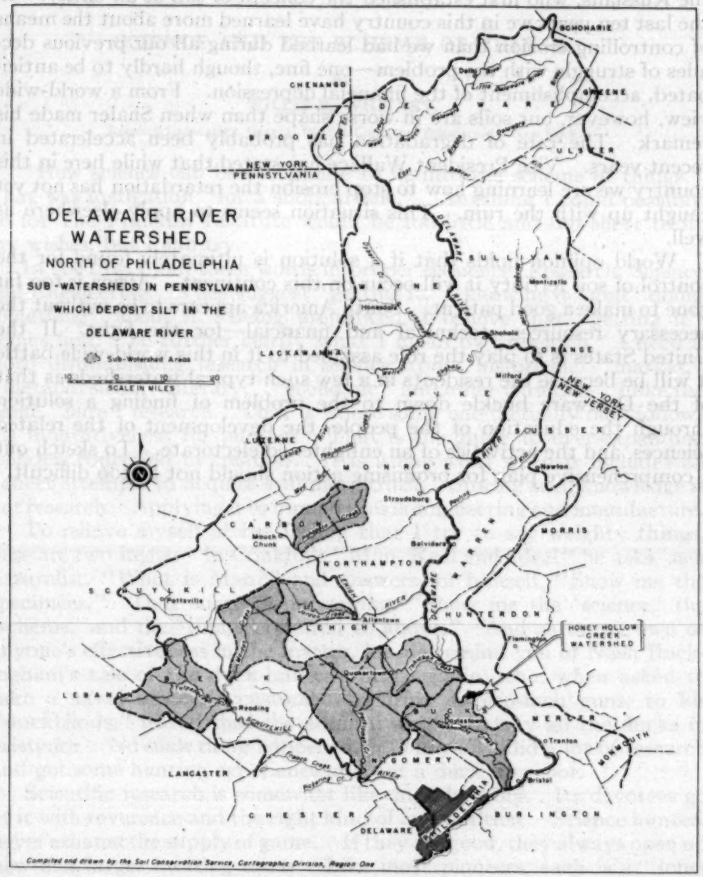


FIG. 7. Silting Philadelphia's water supply.

Note in lower right the 1,000 acre watershed of Honey Hollow Creek—the only sizeable area in the Delaware Valley, Pennsylvania side—which has installed conservation measures.

about soils in the last fifty years, principally through the researches of the Russians, who first established the concept of soil as an entity. In the last ten years we in this country have learned more about the means of controlling erosion than we had learned during all our previous decades of struggle with the problem—one fine, though hardly to be anticipated, accomplishment of the financial depression. From a world-wide view, however, our soils are in worse shape than when Shaler made his remark. The rate of degradation has probably been accelerated in recent years. Vice President Wallace has stated that while here in this country we are learning how to stop erosion the retardation has not yet caught up with the ruin. This situation seems to apply elsewhere as well.

World opinion holds that if a solution is ultimately found for the control of soil fertility it will occur on this continent. Africa is too far gone to make a good patient. South America appears to be without the necessary resources—technical and financial—for the fight. If the United States is to play the role assigned to it in this world-wide battle it will be because the residents in a few such typical watersheds as that of the Delaware buckle down to the problem of finding a solution through the education of the people, the development of the related sciences, and the activities of an enlightened electorate. To sketch out a comprehensive plan for promising action should not be too difficult.

SCIENCE AND THE SCHEME OF THINGS.

BY

WILLIS R. WHITNEY,

Research Laboratory, General Electric Company, Schenectady, New York.

"How science can best be made to fit into the scheme of things." That was instigation "for a short article." Anything I could possibly do for The Franklin Institute would be too little and too short to fit my wishes, but I can try.

In starting I join three words in proper sequence: Research, Science and Engineering. They suggest "getting it," "knowing it" and "doing something" about it. Being prejudiced, I believe that "getting it" comes first. To further clarify what I mean by "research," I need a word distinguishing research in science from "historical," "market," "metaphysical," "library," "economic" and other varieties. I like the name "pure" research. That is where some one (actually one) follows his inquisitiveness for purpose. That is the guide to ever-expanding wonders concealed in creation. It is a fine word when it includes all honest attempts to acquire still more truth. Storing such knowledge is not research. Applying it to human uses is engineering and manufacture.

To relieve myself of the feeling that I try to say weighty things, here are two items. In Conklin's "Man, Real and Ideal" he asks, as a naturalist, "What is Man?" and answers for himself, "Show me the specimens." That suggests my saying, "Show me the 'science,' the 'scheme,' and the 'things' referred to above." And as to my own or anyone's effectiveness in the matter, let me remind you of Nash Buckingham's tale of the duck-hunter's negro guide, who, when asked to take a naval officer, accustomed to firing sixteen-inch guns, to his "duckblinds," feared that the admiral would destroy all the ducks in existence. No such thing happened. "They-all" did a lot of research and got some hunting experience and not a duck was shot.

Scientific research is somewhat like duck hunting. Its devotees go at it with reverence and the right kind of ammunition. Science hunters never exhaust the supply of game. If they are good, they always open up new and larger hunting areas. Like most pioneers, each is a "lone-ranger." On the other hand, "group-research," as in industry, is relatively an innovation and there may be no reason for not employing sixteen-inch guns of representative government for research if it would help exterminate our massive ignorance. That is a question (in military parlance) of "detail." In a world-minded scheme, it would be better if able men of all races experimented on the problems of humanism than on neolithic or modern methods of mutual destruction.

A few curious men are always doing research in science. That is, adding to knowledge of truth by their personal efforts. LaFarge calls them "lonesome men." The public has usually opposed them by starving the abnormal fellow or punishing him for such curiosity. Could it change this method? I don't know. I once assumed that the story of the Garden of Eden was the first case of punishment for human inquisitiveness. It threatened the whole business of creation. But now Jastrow's records of Babylonia, and particularly Breasted's discoveries in his "Dawn of Conscience," show that successful research preceded even hieroglyphic records. Naturally, Charles Lamb's son-of-Hoti, who experimented on fire and pigpens, was punished. That makes me imagine the grief our fellow-researcher felt who first discovered the great advantage of flint over limestone for better tools and arms. Opposition to natural curiosity has always wanted to rule. Read the historical case of opposition to the discoveries of iron and steel by the Delphic Oracle, as described by Herodotus. Then read the religious deprecation of natural curiosity by the Council of Trent, the proposed moratorium on new Science by the Dean of St. Paul's (the "gloomy" Dean), and the general castigation of all capital by the Dean of Canterbury. Note the long imprisonment of Galileo, whose data contradicted the local authorities on the celestial system. Even our Franklin was not free from such critics. I heard a modern political leader declaim on the folly of his tempting lightning by a wet-string conductor. Franklin, as he told us, first took samples of lightning into his "bottles" by the wet kite string guided by a dry silk cord while the operator kept out of the wet. Then he later "shocked" himself and instructed others with his samples.

There are countless cases of this instructive kind. The public is usually merely in doubt. The single curious individual always has to "go it alone," like Darius Green and Professor Langley (dubbed "Green No. 2"). Otherwise he must enlist a brother, as in the Wrights' case, or hated capital as in most cases. The whole complacent world abhors change; yet there is nothing so certain as its continuous change of mind. That is Nature's perpetual motion. I recall the time when Edison was called "a crackpot trying to bottle sunlight." Can we forget Fulton's folly, Faraday's explaining to Mr. Gladstone, "Why, sir, you will soon be able to tax it!" or "What is the good in a baby?" I've seen our man-made laws penalize inventors of horseless carriages for speeds exceeding eight, then fifteen, then twenty-five and thirty-five and fifty miles an hour in turn.

Who forced cow-catchers onto all locomotives, almost before the locomotive could catch up with a cow? Think how Watt, all alone, by empowering steam changed the viewpoint expressed so ably by Adam Smith that "The patrimony of the poor man lies in the strength and dexterity of *his hands*." William Morris's words are also relevant:

V.2
194

"The chief duty of the civilized world to-day is to . . . do its utmost to minimize the amount of unhappy labor." So! How do it? Something suggests further organized search of truth in our untested materials and our character.

I prefer to be with Mark Twain in thinking favorably of individuality in research. He said, "All we need in this life is ignorance and confidence, then success is sure. I would take care of the constellations if asked to do it." We must try things and be prepared for surprises—particularly accidents—but try and try again.

Trying to keep abreast of advances in new knowledge, I forever marvel at the spread of the frontiers of material truth. There we border on infinite undeveloped and unexplored territories. Our old pioneering types may miss the unknown geography of their forerunners, but they are now vigorously exploring the fields where lie most promising opportunities for public welfare. Continued research will clarify our misty intelligence, teach truth and spread more widely the significance of words like Professor Thorndike's "Science transforms a world of fairies, demons, magic, charm and luck into the dependable world of natural law."

I was particularly interested in a recent report in which the Director of the American Museum of Natural History said, "The unknown can obviously not be evaluated in advance, and all knowledge ultimately seems to find a use, if only in avoiding the errors of ignorance."

Professor Breasted, the Egyptologist, shows the discovery of morality, good-will, character and human service to have had a sort of Darwinian and natural evolution already well advanced thousands of years ago. Honesty had been experimentally shown the best policy, clear conscience a great asset, and all new religions advocated them. Complacency was only temporary even in Egypt. What a shake-up there must have been among early authorities when that chap discovered artificial pollination of date palms as depicted on early monuments! He must have been read out of the sun-worshippers for monkeying with the hereafter.

What I am saying is that pure research thus far has been quite personally independent and always unpopular—until after the event. It almost has to steal its freedom. It is appreciated only by its devotees and their confreres. They were never selfishly "local" in their service (except in Bacon's imaginary Bensalem). They spend their own money to learn, and then to spread the facts they disclose, and that, too, to all possible users anywhere. This serves as a way of fixing their thoughts as truth, because of the natural checking tendencies of all curious scientists. Even a government might, conceivably, try an experiment in research without irretrievably plowing under too much of its pork; but it would better be as an experiment than as a dive off the end of the dock.

We have naturally hoped that our own life-work and the story of our Schenectady laboratory would in some way be of service to the American public. It has been a bit difficult to aim that service at the world-at-large, as we wished; but, as scientists have usually plodded forward in that general direction, we may hope for the best after this "duration."

There is a little irony in our national declaration of our endowment with "life, liberty and the pursuit of happiness." Perhaps here is the reason why scientists everywhere pursue unknown things of nature with such burning zeal. It is the pursuit, not the attainment, they are after; the freedom, not the product. Call it the freedom of wild men if you will, but it works.

In 1916 we wrote in support of an experiment in government aid to research—suggested in the Newlands Bill. Criticisms and commendations from many of our science friends were sought by us, and were printed in *Metallurgical and Chemical Industry* for June, 1916. Most of those who contributed are dead and so is the bill; but the scientists did not shoot one another in disappointment. They continued to aim at the advance of science without complaint. There are so many "Freedoms" involved in government subsidies of all kinds that our country has not worked out an answer for aid to science yet; but it might well be tried in the form of some bill. Anyone who has watched the Soviets during the past twenty-five years may visualize possibilities. They have done remarkably with their plans.

Franklin was also one who felt that something worthwhile can always be found through experiment. He said of his favorite science, "If there is no better use discovered by electricity, this however is something considerable, that it may help make vain men humble."

An important fact influencing us in hoping for greater extension of pure research in America is that otherwise we may be outdistanced by those other nations who place higher value on systematic and well-supported science. We might fear what is inherent in that thought or (what is more scientific) we might anticipate the time when former acts of science-novelty shall weld world-peoples so closely together that all may find pleasure in the common pursuit of happiness. This seems possible along the lines of further appreciation of our infinite assets. Radio, aeronautics et cetera should help it. It is not scientific to create national Creators, but in the presence of the real creation, we might join more generally in its processes, properly based upon discoveries which we honestly and diligently make.

In a representative form of government, it should be possible to expand the efforts of science to greater world advantage, but our "set-up" is not quite that of Russia. The Soviets have done wonders in discoveries and applications during the past twenty-five years. This is scarcely understood in America. For example: Do we appreciate the wonderful

work on dog physiology and psychology of Pavlof and how it led to our "blood banks" for the aid of our fighting force? Or do we more than squirm at the recent vivisection researches which their "movies" show us? That work but shows how quickly a whole nation may react to its advantage through scientific effort. The Dean of Canterbury, in his book "The Soviet Power," says, "No country in the world holds science in higher esteem or provides its scientists with better and more ample equipment." We cannot exactly duplicate Soviet history, but we might improve upon it. Freedom of mind is at the base of scientific advance. Opportunity for free effort in curiosity about the beneficent creation is part of the mechanism necessary for advance. Advances in civilization finally follow the discoveries of science in spite of false leaders.

In our democracy there ought to be as little "must" and "directive" as is consistent with the general education of our electorate. Good monarchs or far-seeing representatives are valuable to any nation, but we Americans like to understand things. We want to proceed on our way by exercising the maximum of individual human right rather than by accepting manna fed from above. Scientists may be well or poorly led, but they have never been trained for driving in harness. They hope and contrive individually to contribute to general mental and physical evolution. That has been going on about one million years and was old in cave days as a principle.

We ought to remind ourselves of our National Academy of Science and of the National Research Council which certainly represent the larger part of our American scientists and researchers. These are also in close coöperation with our colleges, universities, schools of technology and trade schools as well as with thousands of industrial research laboratories. Their organizations are in position to help select and assist the promising would-be explorer in the various sciences even back in the high schools and to such representatives as these I would look for the needed appreciation of the peculiar catalyzers desired for a proper national program of research, if to be government supported.

Our federal representatives supposedly represent the whole, or the average, public. They are not particularly familiar with new science. That is not their forte or calling. The Academy and the Council are more representative of science than Congress could possibly be. Twenty-five years ago, Russia, in similar quandary, took advantage of its ancient Academy to determine Soviet policy with respect to research, and now is very glad it did so. To depend on those who are only slightly familiar with the subject to direct the policies would be like asking untrained civilians to execute their preferred war policies.

The public has never appreciated details of new science and has uniformly opposed its logical conclusions until late in the day. Advances made by far-seeing and inquisitive researches everywhere (not

only in America) have come from individuals of abnormal faith and works, against world pressure and opinion. In industry itself, where appreciation of science has so rapidly grown, the public is still somewhat sceptical and even critical. That is no criticism of public representatives, but scientists might do more if supported by more scientific means. When we look back at the ways by which man has traveled towards greater knowledge, we are impressed with the thought that, in spite of their deviousness, he has continually progressed. In the past century it seems a more rapid and orderly rate than ever before though it may not be real. The question naturally arises: "How much better can he do and what experiments may he yet try in research?" There seems to be no ceiling placed by Nature on our human possibilities except what we imagine.

V.2
194

METEOROLOGY IN THE FRANKLIN INSTITUTE.

BY

ARMAND N. SPITZ.

"Some people are weatherwise but most are otherwise."
B. Franklin.[1]

In his customary manner Franklin thus phrased a universal truth in simplest terms. That men have been conscious of the weather from the very beginning of their intelligent existence no person could doubt, but it is also beyond argument that, of all the natural sciences, less was known about the weather and its causes than about almost any of the other phenomena which men observed.

In his character of Poor Richard, Franklin had, for many years, been making his own analyses of weather conditions, and, at intervals throughout his life, he studied and reported upon meteorological phenomena, offering suggestions as to their causes. The field of his investigations was broad. At one time or another he analyzed the causes of cold waves, fogs, thunder gusts, variations of the barometer and the use of thermometers in navigation. It was he who in 1743, made the now widely accepted observation that northeast storms originate in the southwest. This observation, more than any other, perhaps, established him as a capable observer and interpreter in this field, and stamped him, without question, as the leader of meteorological thought in this country in the eighteenth century. Dr. Franklin had outlined his theory in a letter to Jared Elliott on February 13, 1750, and he wrote to Alexander Small from London on May 12, 1760, apparently as a reply to specific questions. Franklin was, at the time, agent in London for the colony of Pennsylvania. This letter outlines the observations he made some twenty years before, when he was prevented from seeing an eclipse of the Moon from Philadelphia because of a northeast storm. Later he discovered, from Boston newspapers and from a letter from his brother, that the beginning of the eclipse had been observed there. These sent him into a series of inquiries concerning the time of the storm's beginning. He concluded that the beginning was "later the farther northeastward."

Dr. Alexander Dallas Bache, Professor of Natural Philosophy and Chemistry at the University of Pennsylvania, Superintendent of the Coast Survey and a great-grandson of Franklin, regarded the theory as having so much significance that he made an elaborate astronomical inquiry to determine the date of the eclipse and storm to which his

[1] *Poor Richard's Almanac*, February, 1735.

forefather had referred. He communicated his results verbally to the American Philosophical Society, and published them in detail, proving that the eclipse occurred on the evening of October 21, 1743.[2]

There was no doubt in Franklin's mind that waterspouts and whirlwinds were similar in all respects except "that the one passes over land, the other over water." [3]

In 1755 he examined a whirlwind closely, in company with Colonel Tasker, in Maryland. In order to watch the miniature cyclone more clearly, he rode beside it, and even tried to break it by striking it with his whip. "Upon my asking Colonel Tasker if such whirlwinds were common in Maryland he answered pleasantly, 'No, not at all common, but we got this on purpose to treat Mr. Franklin.' And a very high treat it was." [4]

At the close of a dissertation on this same subject, Franklin made a comment which, if nothing else he ever did, established him as a worthy spiritual father of The Franklin Institute:

"If my hypothesis is not the truth itself it is at least as naked, for I have not with some of our learned moderns disguised my nonsense in Greek, clothed it in algebra nor adorned it with fluxions. You have it *in puris naturalibus*." [5]

In May, 1784, writing from Passy, Franklin produced a series of "Meteorological Imaginations and Conjectures," talking about the low temperatures aloft, regardless of season; rain, snow, hail, fog, winds, insolation and radiation (although not in these terms), together with other meteorological miscellany. This was read before the Literary and Philosophical Society of Manchester late the same year and was published in the Society's "Memoirs." [6]

One of Franklin's interests, although not primarily meteorological, may well be regarded as the prototype of some modern heating and air-conditioning apparatus, which, themselves, are meteorological applications. "The 'Pennsylvanian Fire-Place' heats fresh outside air and sends it out into the room instead of heating stale room air, while the latter is used for combustion and passes with the smoke up the chimney. Franklin estimated that 'near ten barrels of fresh air are hourly introduced by the air-box; and by this means the air in the room is continually changed, and kept, at the same time, sweet and warm.' The heated air, prevented from going up the chimney by the closure above the fire-place, is forced out in front of the mantelpiece, where it rises to the ceiling and spreads out over the room, to be forced down by streams of newly warmed air. Thus the entire room is warmed and

[2] JOURNAL OF THE FRANKLIN INSTITUTE, November, 1833, p. 300.
[3] Letter to John Perkins, February 4, 1753; read at the Royal Society, June 24, 1756.
[4] "The Writings of Benjamin Franklin," Smyth, Vol. I, p. 59.
[5] *Ibid.*, Vol. I, p. 49.
[6] "The Writings of Benjamin Franklin," Smyth, Vol. IX, p. 215.

there being no continual movement of cold air from the room into the fire-place, strong draughts from cracks around doors or windows are eliminated." [7]

When The Franklin Institute was born, in 1824, to pay honor to Benjamin Franklin, and to further both scientific activities and the understanding of them, it would have been highly illogical if early attention had not been paid to one of his greatest interests. While it was a number of years before there was any organized work in the field of meteorology, it was not long before articles and lectures began to be presented to the public which would have been a delight to the Institute's weather-wise patron, himself.

In the very first volume of the *Journal of The Franklin Institute*, then known as *The Franklin Journal and American Mechanics Magazine*, there were two articles which bore prophetic testimony to the interest which the Institute would shortly be displaying in things meteorological. Air conditioning, as such, was, of course, almost a century away, but even in 1826 the idea of warming rooms by heated air was a novelty. An article devoted to that subject declares that such a method is "very economical and has had its utility established by the ordeal of a fair trial." [8] Franklin himself would have been interested, because of his Pennsylvanian Fire-place.

The same year, in the sixth issue of the *Journal* Dr. Robert Hare, professor of Chemistry of the University of Pennsylvania, explained, "New Method of Demonstrating the Existence, and the Extent, of the Pressure of the Atmosphere." [9] He used four jars, each with about two inches of mercury in the bottom. An additional tube is introduced into each jar, the lower end being under the surface of the mercury. Four separate fluids are then poured into the jars,—water, ether, alcohol and a solution of copper sulphate. The mercury rises in the tube, and some interesting conclusions may be drawn. "The pressure of any fluid upon any area assumed within it, the pressure of a column of any other fluid, having the same area for its base, may be substituted; provided the substituted column be as much higher as lighter; as much lower as heavier; or, in other words, the heights of the respective fluids must be as their gravities, inversely."

Dr. Hare's conclusion as to the extent of the pressure of the atmosphere, is an interesting one:

"The atmosphere, if of the same density throughout, as on the surface of the earth, would not extend much above the elevation ascribed to the highest mountains. But, as the pressure of the atmosphere causes its density, it may be demonstrated, that, the heights increasing

[7] *The Institute News*, Vol. VII, No. 9, January, 1943, p. 4.
[8] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 1, No. 3, March, 1826, p. 163.
[9] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 1, No. 6, June, 1826, p. 362.

in arithmetical progression, the densities will decrease in geometrical progression. Thus the density at 3 miles, being, by observation, one half of what it is at the surface of the earth;

At 6 miles it will be 1/4	At 18 miles it will be 1/64
9 miles it will be 1/8	21 miles it will be 1/128
12 miles it will be 1/16	24 miles it will be 1/256
15 miles it will be 1/32	

or, rarer than we can render it by the finest air pump."

This conclusion is in very close agreement with modern data.

In a two-part reprint from Forster's "Encyclopedia of Natural Phenomena," the Editor of the *Journal* offered a series of "Prognostics of the Weather."[10] one of the first publications of easily observed weather signs, together with their meteorological explanation. The entries run the gamut from *Aches and Pains* and *Drowsiness* to *Rainbows*, *Haloes*, and a large number of other definitely significant phenomena.

An editor's note was appended to the first installment of this article:

"The writer of these Prognostics, has distinguished himself by his researches on atmospheric phenomena, a subject upon which we are, it is believed, more profoundly ignorant than upon any other which has received equal attention. The scraps which are here collected and detailed, by a gentleman of science, may be adduced as a proof of the truth of this opinion. . . . They are presented less for their utility, than as a proof of the extent, or rather of the meagreness of our information upon the subject."

V.2
194

About this time The Franklin Institute, which was conducting a wide variety of courses for young artisans of Philadelphia, employed James Pollard Espy, then principal of the Academy in Cumberland, Maryland, as Professor of Languages. He soon became head of the Classics Department of the Institute, and began his life-long work in meteorology. It had always been an interest, but never had he had the time to devote to it. While there had been others interested and active in the subject, he appears to have been the first person to accomplish anything worth while in meteorological research, and in the scientific classification of the meteorological knowledge of the times.

In 1830 Espy announced the cooling of ascending air by expansion, and about this time he began to devote himself entirely to studying, lecturing and writing on meteorology. His papers were numerous and intensive. He exerted every possible effort to systematize observational methods, and developed forms so that all observers, no matter where they were, would be watching for and reporting on the same things.

In a paper urging men of science to a realization of the importance of making meteorological observations, Professor Espy wrote: "I ask

[10] JOURNAL OF THE FRANKLIN INSTITUTE, August, 1828, p. 99; September, 1828, p. 175.

again why is it that this highly interesting and useful branch of human knowledge makes such slow advances, whilst almost every other department of physical science is receiving important additions every year? . . . Let learned and scientific societies answer to themselves and to the interests of mankind for this egregious neglect. Do philosophers think that no more discoveries can be made on this subject? and that the weather never can be predicted?" [11]

Espy here advanced some of his observations on the importance of the temperature of the dew point as an element in weather forecasting: ". . . When we consider that the quantity of water vapour in the atmosphere is the only constituent which changes its proportion . . . and when we consider that the weather depends so much upon the quantity of vapour in the atmosphere, it becomes highly probable, that cotemporaneous (sic) observations, made on the quantity of vapour alone, in different parts of our widely extended country, would solve the problem of the weather, which has hitherto eluded the researches of the most patient observers." Discussions of thermodynamics of the air, and the semidiurnal variations in barometer readings introduce the readers of the early issues of the *Journal* to the meteorological idea in "an endeavour to awaken an interest in this subject." Espy pounced upon prevailing errors and misconceptions, and advanced his own theories. For the first time this country had the opportunity to watch a scientific mind at work in a field which had hitherto been haphazard in the extreme.

"It is to observations on the rise and fall of the dew point that we must look for means to predict the weather," concluded Espy, "and if this *point* is faithfully attended to the result will be *success*."

One of the ideas which drew Espy's fire was the prevalent notion that "mountains attract clouds." He acknowledges the fact that clouds frequently appear on the sides and near the tops of mountains, and then proceeds to account for the phenomenon "on well established principles, without supposing any mysterious attraction for which no reason has every been assigned." He thus adduces the fundamental theory of adiabatic expansion and demonstrates that "nothing is necessary to produce clouds and rain on the sides of mountains but an ascending current whose dew point, at the base, is near the temperature of the air." He follows this through with a meteorologically adequate explanation of the Rocky Mountain phenomenon of warmer air on the leeward side, what is now known as the "foehn," "chinook" or "snow-eater."

In a presumably authoritative article [12] it had been stated "That electricity is a frequent and powerful agent in the formation of rain is extremely probable. The well known fact that the rain which accom-

[11] JOURNAL OF THE FRANKLIN INSTITUTE, December, 1831, p. 389 ff.

[12] Walsh's "Notices of Brazil," Vol. II, p. 92.

panies a thunderstorm is more copious than in any other circumstances is evidence sufficient that it is frequently modified or increased by the influence of electricity." Accompanying his protest against this conclusion by a discussion of the phenomenon from a number of points of view, Espy declares "the true solution of the difficulty will be found in considering the rain as the cause and the lightning as effect,"—a point of view which is now given universal acceptance.

It is interesting to note that, although Professor Espy's contributions to meteorology while a member of the staff of The Franklin Institute were well acknowledged by his contemporaries, his conclusions were not always unchallenged by them. In November, 1833 he published a paper in which he discussed the flow of air in various levels. He points out a number of coincidences which "appear to me to be very favorable to the production of an aurora borealis. . . . It is now a point well established, that the aurora is in the region of the clouds,' and here the Institute's Committee on Publication inserts an asterisk, referring to a footnote: "We do not consider with our friend that this point has been satisfactorily determined." [13]

So much discussion was aroused by this circumstance, in which the work of British scientists was quoted, that Espy wrote another paper,[14] admitting that many able students considered the question of the height of the aurora yet unanswered,—some leaning to the opinion that the aurora is one hundred miles high. "As a doubt still remains on this subject," he wrote, "I propose to state the evidence . . . in so plain a manner, that it will be impossible for any person, who examines the subject, to reject the conclusion that the aurora is in the region of the clouds." He proceeds to interpret case after case, quoting whizzing, crackling noises, and the sensation of a wind on the face of the observer. He takes issue with observers who espouse the cause of the aurora as an upper atmosphere phenomenon. There is no doubt that he was convinced that he was right,—but even this earnest worker, the most active of the nation's earliest meteorologists, could be wrong.

"Most of the auroral literature, and it is voluminous, is just talk," declares William J. Humphreys.[15] The minimum observation of the lower limits of auroral displays is 100 kilometers.[16]

The next decade found Espy no stranger to dissenters who picked to pieces his development of a theory of storms.

The active interest which was being fostered at the Institute soon made itself felt elsewhere. In Philadelphia, in 1834, a committee con-

[13] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 12, No. 5, November, 1833, p. 295.

[14] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 13, No. 5, May, 1834, p. 295, and Vol. 13, No. 6, June, 1834, p. 363.

[15] "Physics of the Air," Ed. 3, 1940, p. 413.

[16] L. Vegard, Oslo University, "The Aurora Polaris and the Upper Atmosphere" in "Physics of the Earth," 1939, Vol. VIII, p. 585.

sisting of five members of The Franklin Institute, and of four members of the American Philosophical Society, of which Franklin had been founder and first president, were constituted as a "Joint Committee on Meteorology." Espy was chairman of the committee. The other members were Gouverneur Emerson, M.D., C. N. Bancker, Alexander D. Bache, H. D. Rogers, S. C. Walker and P. B. Goddard, M.D. Espy and Bache represented both The Franklin Institute and the American Philosophical Society, although Espy was not elected to the latter Society until the following year.

The Franklin Institute was made the clearing house for all meteorological observations, and all reports were either to Espy as chairman, or to William Hamilton, Esq., then Actuary of the Institute. It was decided to make detailed studies of specific storms. The first report [17] acknowledges the receipt of detailed weather records or "journals" from a number of people who had received the original circular of the Joint Committee. "Only four months have elapsed since the reception of the earliest of these journals, and already some valuable facts have been deduced from a comparison of the simultaneous observations which they contain."

The reports are summarized, and then a series of significant questions is outlined.

"The committee desire these remarks to be viewed as they are intended, to be confirmed or rejected as future observations, and a more extensive induction, shall warrant. They merely propose the queries:

"Are rains caused by an upward motion of air, commencing where the dew-point is highest, or where the barometer is lowest?

"Do storms in the temperate zones generally travel from some westerly point? And are those storms which so travel preceded by an easterly wind, and also followed by a westerly, unless another storm is soon to come on in the same direction? In the torrid zone, do the storms on the north side of the line travel toward the north-west, and on the south side of the line toward the south-west?

"Is this (about twenty-six miles an hour) the velocity of the upper current of air at Philadelphia, which comes generally from a point south of west? Is it this upper current which gives direction to the storms in this latitude?

"What are these two diameters of storms generally?" (Referring to a specific storm with a north-east and south-west diameter, at Nashville, of about 200 miles, gradually increasing in size until, at Portsmouth, it was 800 miles. Its north-west and south-east diameter was unknown.)

The first report ends with a plea:

[17] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. XVI, No. 1, July, 1835, p. 4 ff.

"The committee earnestly request that the present opportunity of discovery not be lost, that the undertaking may not languish for want of zeal; their correspondents may be assured, even when the committee is silent, that they are constantly at their posts, waiting for the communications with that intense interest which always accompanies sanguine hopes of successful investigation."

The second report[18] opens with "regret that the extent of our correspondence north-west and south-east is not great enough to ascertain the boundaries of our great storms in those directions; and of course we cannot determine the direction of winds in those boundaries—a knowledge which we believe to be of the highest importance to the science of meteorology. The committee do not yet despair, however, of extending this correspondence so far as to attain so desirable an end, and with the hope of aiding this extension, proceed to give an account of a few of the most remarkable storms which have occurred since their first report. These we are sure will be found to be highly interesting, even with the imperfect knowledge which our limited correspondence enables us to give of them. . . . It is much to be hoped that the gentlemen throughout the country who may see this report, will communicate to us any fact connected with the storms here detailed, which may be either favorable or adverse to the generalization upon which we have ventured. . . . The labor, though great, of collating numerous journals, and deducing from them general conclusions, will be cheerfully continued by the committee. These journals are carefully preserved in the archives of the Franklin Institute, and will be accessible to any meteorologist who may wish to consult them."

V.23
1944

And then follows the theme about which the second report is built: "to enable the reader to comprehend the report with greater ease, we recommend him to bear in mind this remarkable generalization—*In all the seven storms examined, the wind blew towards the point where it was raining.* To this rule there is not one exception."

The report concludes:

"It is a remarkable fact, and altogether consistent with the generalization here spoken of, that all our great storms which set in from some eastern point, terminate with the wind from some western point; and our correspondents will recollect that all the phenomena detailed in our first report lead to the same conclusion. Among the storms there detailed, not the least remarkable was that on the 22d of March, 1835, in which there was a perfect calm at Philadelphia for several hours, with an extremely low barometer, the sky was very cloudy, without rain, while at the same time there was a most violent rain all around Philadelphia, with very strong winds towards Philadelphia.

"Was the air at this moment rising over Philadelphia so rapidly as to carry up the drops of rain and throw them off at the sides of the

[18] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. XXI, No. 6, June, 1836, p. 386 ff.

ascending column? Both the rapid afflux of air towards Philadelphia, at that time, and the extreme depression of the barometer there, lead strongly to an affirmative answer. How extremely interesting would it be if our correspondence were wide enough to trace these storms to their commencement, and follow them to their termination.

"And if our present attempt should fail to stimulate men of science to engage in the undertaking of investigating the dynamical laws to which the movements of the atmosphere are subject, and this can only be done by simultaneous observations over a wide extent of territory, then this committee, *unless aided by the Government*,[19] will have to leave the work unfinished, and reluctantly close their labors, with perhaps one more report."

At the conclusion of the report, Espy published some remarks in connection with a very violent hail and rain storm (Fig. 1).[20]

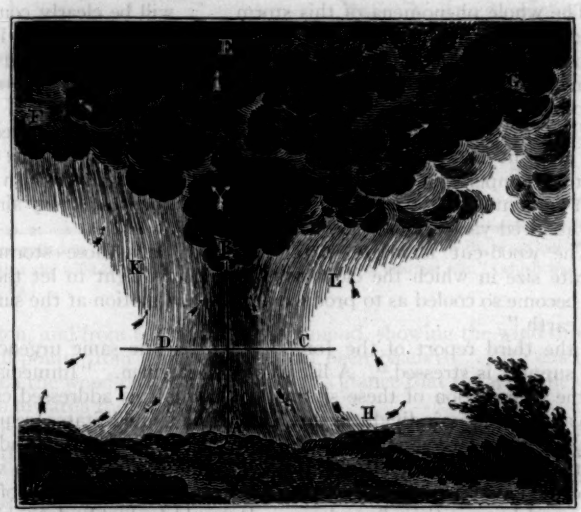


FIG. 1. "The wood-cut is intended to represent only those storms of moderate size in which the cloud is of sufficient height to let the air below become so cooled as to produce an outward motion at the surface of the earth." (1835)

"If we suppose A, B, in the accompanying wood-cut, the distance of the lower part of a cloud, producing a violent rain, to be one thousand yards, and this whole stratum to be cooled down ten degrees of Fahr.,

[19] The insinuating italics are *not* mine. A.N.S.

[20] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. XXI, No. 6, June 1836, p. 391 ff.

which is a moderate allowance both as to height and temperature, the density would be increased about 1/50th, and of course, it would overbalance, by its superior weight, the columns of air on the outside of the rain, at I and H, and move outwards from the centre of the storm, at the surface of the earth, with a velocity due to a head of pressure of $\frac{3000}{50}$ feet or $\sqrt{8} \times \frac{3000}{50} = 62$ feet per second. Whenever a hard shower takes place from a lofty cloud of moderate diameter, such will be the effect at the surface of the eath. For as the perpendicular diameter of a cloud, which produces a very hard rain, must be very great, the drops of rain must descend from a great height, and will enter this lower stratum of air very cold, sometimes frozen; the effect will be manifestly as stated above. . . .

"The whole phenomena of this storm . . . will be clearly comprehended by supposing that there is an inward motion of air at the lower part of the cloud, an upward motion in the cloud, and an outward motion in the upper part of the cloud, as indicated by the arrows in the woodcut.

"This upward motion also, if it could be shown how it is effected, would account for the condensation of the vapour into rain by the diminution of temperature resulting from diminished pressure, which it is known amounts to at least one degree Fahr., in the case of dry air, for every hundred yards of ascent.[21]

"The wood-cut is intended to represent only those storms of moderate size in which the cloud is of sufficient height to let the air below become so cooled as to produce an outward motion at the surface of the earth."

In the third report of the Joint Committee the same urgency of public support is stressed.[22] A list of storms is given. "Immediately after the termination of these storms, the committee addressed circulars to a great many individuals throughout the United States, requesting an account of them, particularly with regard to the rain, and the strength and direction of the wind. Our inquiries were not in vain. We received very satisfactory replies from many in the region of the storms, and beyond their boundaries. It would be highly desirable to give the documents to the public, entire, but our present means will not permit.

"It is hoped that when government shall become acquainted with the important discoveries already made, and the absolute necessity of combined and simultaneous exertions, beyond the reach of individuals, their liberality will be cheerfully extended to the promotion of this science, in our widely extended country."

---

[21] Actually, in the case of dry air, nearer to 2° per hundred yards. A.N.S.

[22] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. XXIII, No. 1, January, 1837, p. 17 ff.

After citing a large number of observations, the statement is made that "there is therefore the strongest reason to believe that rain is caused by the cooling produced by the rarefaction of the air in its upward motion in the center of the storm."

A wood cut is published in connection with the storm of June 19th to 21st, 1837 (Fig. 2), covering a territory from Cincinatti (sic) to

FIG. 2. A synoptic map of the storm of June 19 and 20, 1836, prepared by compiling reports mailed to The Franklin Institute. "By casting the eye on the wood cut, it will be seen that the wind blew on all sides towards the point of greatest rain" (which was at Silver Lake, Pa.).

Boston, and from L. Ontario to Richmond, showing the wind directions at all points from which reports had been received. "By casting the eye on the wood-cut, it will be seen at a glance that the wind blew on all sides towards the point of greatest rain."

This is one of the first birds'-eye-view weather maps of a specific weather phenomenon to be published in this country, if not *the* first.

"From all these facts, in connection with those detailed in our previous reports, it is, we think, abundantly proven, that the air moves inwards towards the center of great rains, and consequently upward in the region of the cloud. Nor is this inward motion difficult to account for. It has long been known that the barometer stands low in the middle of great storms, and nothing is more plain than that the air will run on all sides towards the point where the barometer stands lowest, with a velocity proportional to the square root of the depression. And as this air mounts upwards over the point where the barometer stands lowest, a condensation of the vapour must take place from the cold produced by diminishing pressure as it ascends. Now, the chairman

of this committee has shown by calculation from acknowledged data, that for every pint of water which is formed by condensation of vapour, the cloud itself is expanded 7600 pints by the latent caloric given out at the moment of condensation. Thus will the upward motion in the cloud be continued as long as air highly charged with vapour runs in below.

"It is also easy to explain why the base of the cloud, during this rapid motion of the air upwards, remains nearly at the same level. For so long as the dew-point of the air at the surface of the earth, which supplies the ascending column with vapour, remains the same, if the temperature of the air is the same also, it will have to ascend to the same height, before cold enough is produced by expansion to cause condensation of the vapour. This height is found to be about 100 yards for every degree between the temperature of the air and the dew-point, unless when the cloud becomes of great perpendicular depth, when the base sinks a little from the levity of the cloud.

"The quantity of depression of the vapour as well as of the air, after due allowance is made for the fall of the dew-point from the expansion, is nearly 400 yards for a depression of the barometer one inch, on the supposition that the temperature of the air sinks 4° for a diminution of pressure equal to an inch of mercury."

V.2
194

The members apparently held the opinion that it was time to be outspoken in asking for public support in order to make the study of meteorology a permanent and nationwide function. The third report no longer *hints* at the desirability of government aid. It states definitely what *should* be done, and outlines the functions of a government meteorological service—the first specific recommendation of a Weather Bureau.

"We would suggest as the most effectual, and perhaps the only, means of obtaining this end, an appropriation by government for the purchase of meteorological instruments, to be presented to those academies, schools and colleges, that would pledge themselves to keep a journal of the weather, according to a prescribed plan, for five years; and send a monthly statement to a meteorologist, to be appointed by the government. If instruments were thus furnished for 100 observers, it is altogether probable 200 more would volunteer their services, knowing that their labours would be one hundred fold more valuable in combination with others than they had hitherto been.

"With 300 observers, properly located, no storm could spring up within, or enter the United States, without being constantly under the eye of at least two observers. And thus its extent, its progress, and the direction of wind in its borders, would be fully known. Until this shall have been effected by government, we entreat every gentleman to whom the report is sent, to consider it a patriotic duty to furnish the means of enabling at least one faithful observer of the weather, to

transmit a series of observations monthly, to Wm. Hamilton, Esq., Actuary of the Franklin Institute, Philadelphia."

There is a documentary gap in the records, at the present time, which may, at some time be closed up, but the fact remains that the Joint Committee got what it wanted.

"Mr. John Cresson stated at the late session of the Legislature of this State, a law was past appropriating four thousand dollars for the promotion of Meteorological Sciences & that the Governor was thereby authorized to draw his warrant on the State Treasurer in favor of the Treasurer of the Franklin Institute for two thousand dollars on the first day of April, 1837, and for one thousand dollars each on the first day of April 1838 & 1839—" [23]

Immediately orders were placed for barometers, thermometers and rain gauges. The standard instruments, with which all the others were to be compared, were placed at the Institute. Mercurial barometer No. 1, made by L. C. Francis, of Fetter Lane, Philadelphia, under the State appropriation, is still on display in the Museum of the Institute. The present whereabouts of the other standard instruments, as well as those which were distributed to coöperating observers, is at the moment unknown, but it is hoped that some information will be forthcoming to find their present location, and, perhaps, to bring them back to the Institute for permanent display as a part of the history of early meteorology in the United States.

Forms for the use of observers were drawn up, printed and circulated, and these forms, almost without change, were carried on for nearly a half century of the Institute's continued weather service (Fig. 3), and were taken over by the State and later the Federal agencies.

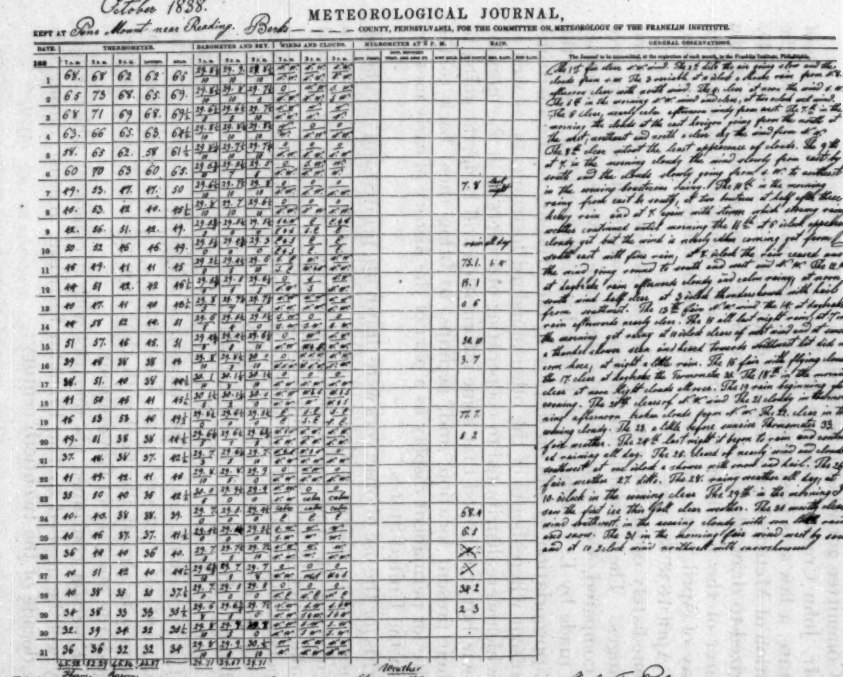
A perspective review of the work of the Joint Committee was given before the American Philosophical Society by Dr. Emerson about thirty years later.[24] He told of the interest which led up to the inauguration of the Joint Committee, outlined its original deliberations, its "collection of observations, and other measures calculated to promote the advancement of meteorological knowledge . . . the programme of their plan was almost identical with that now proposed to be carried out under the auspices of Government."

Dr. Emerson continued his remarks with a comment which might equally well be applied to The Franklin Institute, at least, during this middle decade of the twentieth century:

"For carrying out the projects of the 'Joint Committee' money was needed. This could not be advanced by our Society, then in a position

[23] Minutes of meeting of Board of Managers, April 19, 1837.

[24] *Proceedings of the American Philosophical Society*, Report of Stated Meeting, October 21, 1870, Vol. 11, p. 516 ff.


October 1838.

METEOROLOGICAL JOURNAL,

KEPT AT Pine Mount near Reading, Berks — — — COUNTY, PENNSYLVANIA, FOR THE COMMITTEE ON METEOROLOGY OF THE FRANKLIN INSTITUTE.

DATE.	THERMOMETER.					BAROMETER AND SKY.			WIND AND CLOUDS.			HYGROMETER AT 9 P. M.		RAIN.			GENERAL OBSERVATIONS.
1838	7 A.M.	2 P.M.	9 P.M.	MEAN.	MEAN.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	DEW POINT.	WEIGHT OF VAPOR IN GRS.	QUAN.	TIME.	DUR.	The Journal to be transcribed, at the expiration of each month, to the Franklin Institute, Philadelphia.
1	68.	68	62	62	65	29.8 / 10	29.8 / 10	29.8 / 10	W clear	W clear	W clear	47	4.6				The 1st fair clear & w[arm]. The 2d like the 1st going either and the clouds from s.w. The 3 variable, & a cloud, a shock rain from S.W. afternoon clear with wind and. The 4th fine & warm the wind s.w. The 5th in the morning 47 w. wind cloudy, & the rain set in.
2	65	73	64	65	69.	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				The 6 clear, warm & calm, afternoon cloudy from west. The 7th in the morning the clouds of the last benign going from the north &
3	64	71	69	68.	69½	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				the wind northwest and still & clear by the mid-forenoon of the
4	63.	66	63.	63.	64½	29.8 / 10	29.8 / 10	29.8 / 10	W.	W.	W.	47	4.6				8th clear without the least appearance of clouds. The 9th
5	58.	63	62.	58	61½	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				at 8 in the morning cloudy, the wind cloudy from calm by
6	60	70	63	60	68.	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				south and the clouds cloudy going from s. to the northwest
7	49.	55.	47.	47.	50	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6	7.8	half night		in the morning southerly cloudy. The 10th in the morning
8	46.	63.	48.	46.	54½	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				raining fresh east & easterly, at the bottom of Leff's gap & there
9	48.	56.	51.	48.	49.	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				hilley rain and at 8 again with it & cloudy & raining
10	50	52	46	46	49.	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6	rain all day			weather continued until morning the 11th 8 o clock appearing
11	46	49.	41	41	45	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				cloudy yet but the wind a rising & the rain coming yet from
12	44	51	42.	42	46½	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				south east with fine rain, at 9 it ceased the cloud cleared and
13	40	47.	41	40	40½	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6	7.8	l. a.		the wind going around to south and west and at 10 a.m. The 12th
14	44	58	52	44.	51	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				the wind going around to south and calm raining, at noon
15	51	57.	46	46.	51	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6	1.1			at half past 1 cloudy and clear, at 2 still cloudy and clear
16	39	46	36	38	44	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				from southwest. The 13th fair & w[arm] and the 14th stopped
17	36.	51.	40	36	44½	30.1 / 10	30.1 / 10	30.1 / 10	S.W.	S.W.	S.W.	47	4.6	0.6			rain afternoon cloudy calm. The 15th still and night rain at 7 in
18	41	59	46	41	44½	30.1 / 10	30.1 / 10	30.1 / 10	S.W.	S.W.	S.W.	47	4.6				the morning set cloudy & rained clear of and wind to west &
19	46	53	50	46	47½	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6	7.7			the northwest clear & calm and cloudy. The 16th a thunder shower
20	49.	51	38	38	44½	29.6 / 10	29.6 / 10	29.6 / 10	S.W.	S.W.	S.W.	47	4.6	1.2			about 1 in the afternoon and evening clear, at night a little rain. The 17th
21	37.	46.	36	37.	42½	29.7 / 10	29.6 / 10	29.7 / 10	S.W.	S.W.	S.W.	47	4.6				fair with flying clouds rain clear, at night a little rain. The 18th fair with
22	41	49.	42.	41	44	29.8 / 10	29.8 / 10	29.8 / 10	S.W.	S.W.	S.W.	47	4.6				flying clouds the 19th clear at daybreak the barometer 30. The 18th in the
23	35	50	40	36	42½	30.2 / 10	30.2 / 10	30.2 / 10	S.W.	S.W.	calm	calm	calm				morning clear & very light clouds & rain. The 19 rain beginning Friday
24	40.	46	38	38.	39.	29.7 / 10	29.8 / 10	29.8 / 10	calm	calm	calm	calm	calm	5.8			morning. The 20th clear, & w[arm]. The 21 cloudy in the morning
25	41	46	37.	37.	41½	29.8 / 10	29.8 / 10	29.8 / 10	W.	W.	W.	W.	W.	6.1			afternoon from clouds began & w[arm]. The 22d clear in the
26	36	48	40	36	40.	29.7 / 10	29.7 / 10	29.8 / 10	W.	W.	W.	W.	W.	X			morning cloudy. The 23 a little before sunrise thunder &
27	40	51	42	40	44½	29.8 / 10	29.8 / 10	29.7 / 10	W.	W.	W.	W.	W.	X			fair weather. The 24th last night I began to rain and continued
28	40	38	32	32	37½	29.7 / 10	29.7 / 10	29.8 / 10	W.	W.	W.	W.	W.	3.2			raining all day. The 26 cloud of nearly cloud and clouds
29	34	36	33	33	34½	29.8 / 10	29.8 / 10	29.8 / 10	W.	W.	W.	W.	W.	2.3			southwest & cool & clear & clouds with cloud and clear. The 27
30	32.	39	34	32	34½	29.8 / 10	29.8 / 10	30.1 / 10	W.	W.	W.	W.	W.				fair weather 27 clear. The 28 raining weather all day &
31	36	36	32	32	34	29.8 / 10	29.8 / 10	29.8 / 10	W.	W.	W.	W.	W.				10 o clock in the morning clear. The 29th in the morning &
	1.4.38	12.37	4.8.38	11.37		29.77	29.87	29.91									over the frost ice this first clear weather. The 30 month clear
	Highest — 73																wind southwest in the morning cloudy with rain & rain
	Lowest — 32																wind rain. The 31 in the morning fair wind west by south
	Mean — 29.85																and it is cloud wind northwest with snow[illegible]
	Mean — 29.96																
	Mean — 29.87																

Weather
Clear — 13
Cloudy — 18
31

Signed by Charles F. Egelmann Observer

FIG. 3. The observation form used by the first organized weather watchers. This form, with minor changes, was carried on when the Federal Government began its work in meteorology.

of pecuniary embarrassment, nor by the Franklin Institute, which, strange to say, in this great city, where it should be cherished as a grand capitol of the industrial arts creating most of wealth, has always been comparatively poor."

Dr. Emerson also tells, in this address, that he delivered lectures on meteorology for several years before the class of the Franklin Institute. An interesting item, of continued significance today, is his expression of opposition to the words "fair," "rain," etc., as found on some barometers manufactured even today. Instruments for meteorological research do not have these words inscribed upon them, and apparently have not had, ever since the barometers ordered by the Joint Committe.

"In reference to the barometers made for distribution in this State, it is worthy of notice that they do not contain the European inscriptions on their scale plates, 'fair,' 'set fair,' &c., which, as I have already stated, are calculated to mislead observers on the western side of the Atlantic and bring the instrument into discredit. Another reason for omitting the inscriptions exists in the fact, that many of the barometers went to points in the State so greatly elevated as to render deceptive and useless any inscriptions made on scales graduated from the sea level. The main consideration of the Committee was to ascertain the fluctuation of the mercurial column as influenced by atmospheric conditions." From the barometric viewpoint, it also the main consideration of meteorologists today.

A handbook was published, giving directions for making meteorological observations, including the reading and correction of the instruments sent out. The use of self-registering thermometers was explained, as well as the barometer, stressing the importance of noting the moment of the greatest depression. Dew-point, clearness of sky, precipitation and general observations were outlined for the non-technical observers who might be enlisted in the program.[25]

The first suggestion that upper air observations might have extreme significance is also found in this little handbook. The section on winds and clouds is most precise. It suggests that winds be rated in velocity from 1 to 10, 1 being a light breeze, and 10 the most violent hurricane.

"Should the wind be a moderate breeze from the N. and the clouds moderately fast from the W.S.W. the whole would be marked $\frac{\text{W.S.W.2}}{\text{N.2}}$; and should the air be nearly calm below and the clouds very fast, in the same direction as before, it would be noted $\frac{\text{W.S.W.5}}{\text{N.1}}$; but in case there should be two or three currents of clouds, the fact must be noticed

[25] A copy of the first edition of this handbook (1837) may be found in the archives of the American Philosophical Society. A copy of the second edition, published by the Committee on Meterology of The Franklin Institute in 1854, is on display in the Institute.

among the general observations, or thus: $\frac{W.1}{S.2}$ / $\frac{}{N.W.2}$: the uppermost letter being the upper clouds, the middle letter the lower clouds, and the lowest letter the wind; the velocity of each current being expressed by numbers as above."

Observers of these early days were acutely conscious of their privilege in being able to share in the work which attended the infancy of a science. The amount of detail to which they went in preparing their reports, and commenting upon phenomena which they thought might possibly be significant, bears testimony to the need which was being met by this new and expanded activity.

In such a series of observations by men of enthusiasm for something which they had never been able to experience before, it is not surprising that frequent collateral comments are made which throw a gleam of human interest into the work which built American meteorology into the systematic observational program which it is today.

When he sent in his report of observations for the month of January, 1838, Jacob Lefever of Gettysburg, appended a note in the lower left corner of his finely written tabulations: "Please to excuse the errors and scratching in the days above—occasioned by the babbling of a drunken man—as I have hardly time to prepare a new copy."

The Joint Committee on Meteorology of the American Philosophical Society and The Franklin Institute was dissolved after its third report achieved the end of having meteorological research underwritten by the State. A new Committee on Meteorology of The Franklin Institute was formed, under the chairmanship of Robley Dunglison, M.D., the other members being Alexander D. Bache, Charles N. Bancker, John K. Kane, Henry D. Rogers, Sears C. Walker, R. M. Patterson, M.D., John C. Cresson, Gouv. Emerson, M.D., and Espy. Espy, by this time, had been appointed Meteorologist of the Institute, and was charged with the collation and interpretation of all data which thereafter came to the hands of the committee.

An extraordinary storm immediately preceding the vernal equinox of 1838 was the occasion of the gathering of information from all over the country. The new committee's first report,[26] dated July 9, 1838, transmitted the finding of the Meteorologist to the Board of Managers of the Institute.

The detailed reports of fifty observers were carefully analyzed. In addition Espy drew upon newspaper reports of the days immediately following the storm, and from this weight of evidence, constructed what was to be the first of a long series of synoptic weather maps,

[26] JOURNAL OF THE FRANKLIN INSTITUTE, Vol. XXVI, No. 3, September, 1938, p. 161 ff.

showing how weather might be studied when looking at it in plan (Fig. 4).[27]

After the publication of this report, Espy began to gather together the material he had collected during his years at the Franklin Institute. At his home, at 449 Chestnut Street, he had a small yard which was filled with vessels of water and numerous thermometers for determining the dew-point. The yard was enclosed by a fence of smooth plank, painted white, but it was latterly so covered by figures and calculations "that not a spot remained for another sum or column." [28]

In 1839 and 1840 Espy was invited to appear before the British Association for the Advancement of Science at Glasgow to expound and defend his ideas on the theory and cause of storms. He also addressed the French Academy of Sciences, which appointed a committee including Arago, Pouillet and Babinet, to study the Espy theory. The end of the report is interesting:

"The committee expresses, then, the wish that Mr. Espy should be placed by the government of the United States in a position to continue his important investigations, and to complete his theory, already so remarkable, by means of all the observations and all the experiments which the deductions even of his theory may suggest to him, in a vast country, where enlightened men are not wanting to science, and which is besides, as it were, the home of these frightful meteors." [29] The illustrious Arago, himself a great figure in the physical science, and frequent contributor to the JOURNAL OF THE FRANKLIN INSTITUTE, is said to have remarked, "England had its Newton, France its Cuvier, and America its Espy." [28]

When Espy returned to America he completed his famous "Philosophy of Storms," and included in it not only the several papers published in the Institute *Journal*, but data which was reported to him from other sources. He includes many of the objections of those who vehemently disagreed with his theories on the structure of storms.

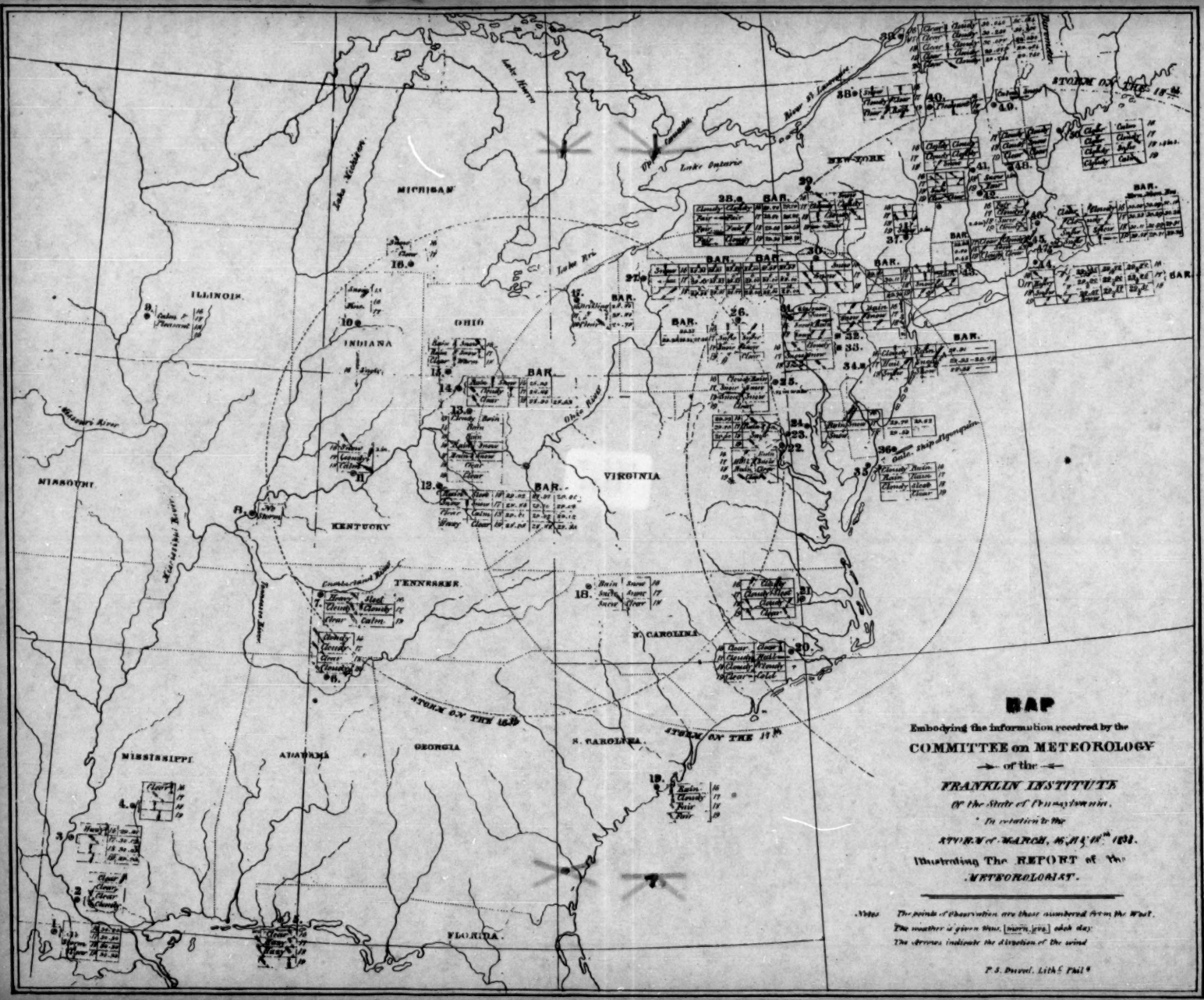
In 1842 Espy was appointed Meteorologist to the United States Government by Congress, and was assigned to duty under the Surgeon-General of the United States Army. In his reports in this capacity he used the same observational forms and weather maps as had earlier been adopted by The Franklin Institute.

(To be continued.)

[27] On the engraving it will be noted that the map was attached to Volume XXII, and not to Volume XXVI. This is due to a change in the system of numbering volumes after the first series.

[28] "A Few Incidents in the Life of Professor James P. Espy." Mrs. L. M. Morehead, Cinncinnati, 1888.

[29] "Philosophy of Storms," p. xxxviii. Published by Charles C. Little and James Brown, Boston, 1841.



MAP

Embodying the information received by the

COMMITTEE on METEOROLOGY

of the

FRANKLIN INSTITUTE

Of the State of Pennsylvania,

In relation to the

STORM of MARCH, 16, 17, 18th 1834.

Illustrating The REPORT of the METEOROLOGIST.

Notes The points of Observation are those numbered from the West.
The weather is given thus, [morn. eve.] each day.
The Arrows indicate the direction of the wind

P. S. Duval. Lith.r Phil.a

ARMY AND NAVY NOTES.

Improvements in Optical Glass.—E. W. NELSON. (*Ceramic Age*, Vol. 42, No. 3.) One of the most useful glasses the Bausch & Lomb Optical Co., has made is an absorptive type to protect the eyes against the intense illumination of the upper atmosphere. At the levels flown by both civilian and military aircraft today, pilots are subject to a very disturbing glare. The effects of high and continuous absorption or radiant energy by the eye are very deleterious. This glass was worked out to provide a transmission curve corresponding to the natural visibility curve of the eye which has a peak with yellow-green portion of the spectrum, while it also acts as a selective filter to remove or reduce infra-red and ultra-violet radiations.

Many types of absorption lenses have been developed for military purposes, such as a new red filter which enables aerial gunners to follow tracer bullets in daylight. Such a lens cuts off the blue radiations sharply and provides a gray background against which the tracer bullets are visible. Most of the developments must await the conclusion of hostilities, however, before detailed information can be disclosed.

One of the really great advances in increasing the light transmission properties of lenses has been the introduction of successful methods of coating surfaces to reduce reflection. Strange as it may seem, until recent years little has been done about this, although it was in 1892 that H. Dennis Taylor accidentally discovered that a slightly corroded surface on some old photographic lenses gave them a higher transmission of light than new ones of a similar type.

In the last few years, however, experimental work has been done by a number of investigators, among them Dr. A. F. Turner and Dr. Frank L. Jones of Bausch & Lomb Scientific Bureau. The theory of thin film on glass surfaces is known and successful applications of it have greatly improved many military instruments in use today.

While the amount of light lost by reflection at the surface of a single lens appears small—from 4 to 6 per cent. depending on the refractive index of the glass—the cumulative effect in an optical objective comprising four free elements is great. The eight air-to-glass surfaces in such an objective will cause a loss of 30 per cent. And this many surfaces is a very common construction. Some optical systems incorporate as many as 20 or more air-to-glass surfaces, each contributing to the loss of light and a reduction of image formation.

There are three methods of treating a lens surface to reduce reflection. The surface may be chemically etched. Successively applied non-molecular layers of certain metallic soaps may be applied, or a salt, such as a fluoride, may be evaporated in vacuo with the vapor stream condensing on the lens surface. Any transparent homogeneous layer in optical contact with a glass surface of higher refractive index will reduce the reflection.

R. H. O.

A PROPOSED SPECTRAL SENSITIVITY INDEX TO DESCRIBE PHOTOGRAPHIC EMULSIONS.

BY

D. R. WHITE.

A considerable amount of work has been done during the past years concerning the measurement and designation of the relative spectral sensitivity of photographic emulsions. The most complete and exact measurements have been made with the aid of spectrographs and various specialized instruments (1). The results have frequently been expressed as curves of sensitivity versus wavelength. Such data, while complete, are not in convenient shape for general use and reference since they give more information than can be used for many purposes.

At the other extreme, there is widespread use of descriptive terms, which purport to give some information concerning spectral sensitivity of emulsions. Such widely used terms include the common descriptions of emulsions as non-color sensitized, orthochromatic, or panchromatic. These classes are subdivided in some cases, as indicated by the terms high red-pan, or high green ortho. The common acceptance of these terms tends to conceal the fact that actually there is little quantitative significance which can be attached to them, in spite of their years of use.

Intermediate between these two extremes are methods of indicating spectral sensitivity through use of color charts or filters (2). In a review of this general problem of measurement of spectral sensitivity, undertaken as a result of an assignment in a subcommittee of the American Standards Association, it appeared to the author that systematic use of a limited amount of filter factor data might be of considerable practical value in specifying color sensitivity. The literature shows many attacks on this problem by this general method. Some workers have shown that considerable information can thus be presented and used, but there has been no general agreement on filters to be used in making such tests and on the form in which the results should be presented to make these results of wide appeal and usefulness.

This article outlines a specific method of test and a proposed form for presenting the results together with equations showing calculations which may be made from the resulting data. Comparisons are given showing many cases of good agreement and a few cases of poor agreement between calculated values and corresponding quantities determined by direct experiment. The results indicate clearly that the information contained in the proposed spectral sensitivity index is of sufficient breadth and precision to be a very practical indication of this emulsion characteristic.

The chief value of the index appears to be in the simple, concise presentation which it gives of this quantitative data concerning spectral sensitivity of the emulsions for which it is determined.

In outline the proposal consists of a division of the spectrum from a standard source into a small number of parts by sharp cutting filters and a calculation of the per cent contribution of each portion of the spectrum of the basic or white light exposure. It is proposed to express the final results on a logarithmic scale, ignoring differences of less than $\sqrt[3]{2}$ in the figures for per cent contributions of different regions.

The relation between the figures representing the per cent contribution of a given spectral region and the more complete spectral sensitivity data mentioned before is readily established on the basis of the additivity of photographic exposures. Suppose that irradiances E_1, $E_2 \cdots E_n$, differing in spectral composition, be determined such that for each exposure density D is produced in time t. Then, it has been shown (3) that density D will also be produced in time t by an exposure

$$(\delta_1 E_1 + \delta_2 E_2 + \cdots + \delta_n E_n)t$$

if

$$\delta_1 + \delta_2 + \cdots + \delta_n = 1.$$

Complete spectral sensitivity data can be expressed in a form which shows the irradiance, E_λ, within a wavelength interval $\Delta\lambda$, required to produce density D in time t. Then any composite exposure which also produces density D in time t may be considered as a sum of parts where the fractional contribution of any wavelength interval $\Delta\lambda$ (corresponding to one of the δ's above) is given by

$$\frac{H_\lambda}{E_\lambda},$$

where H_λ, representing the irradiance from the source, is measured, of course, in the same units and for the same interval $\Delta\lambda$ as $E\lambda$. That is, for composite exposure postulated,

$$\Sigma \frac{H_\lambda}{E_\lambda} = 1.$$

It is at once evident that the fractional contribution of any portion of the spectrum appreciably larger than $\Delta\lambda$ may be computed by summing the values of H_λ/E_λ over the limited portion specified.

After consideration of spectral characteristics of current photographic emulsions in widespread use for pictorial work, it was decided to consider the spectrum as divided into three parts, the parts extending respectively from 350 to 520, 520 to 600 and 600 to 675 millimicrons. Several considerations dictated this choice. In the first place, the one standard source generally recognized in sensitometry is the Inter-

national Standard of Photographic Intensity (4). This source has practically no energy at wavelengths shorter than 350 mμ, and in fact, is low in energy in that region. Hence, if filter factor methods are to be used with that source, the short wavelength limit that can be practically considered is set by the source itself. Again, experience shows that typical silver bromide negative emulsions have sensitivity somewhat beyond pure spectral blue, but that a division at 520 millimicrons will normally serve to distinguish between non-color sensitized and dye sensitized emulsions. The third point, 600 millimicrons may be considered the short wavelength limit of red in the spectrum and hence is a suitable point to use in an attempt to distinguish between orthochromatic and panchromatic emulsions. The long wavelength limit chosen is somewhat arbitrary, but was selected after inspection of spectrograms of current commercial emulsions of different manufacture. There are quite a few emulsions available which have appreciable sensitivity at still longer wavelengths, but they are rather special purpose emulsions, not those now generally used for pictorial purposes. The steps to be used in extending the procedure outlined here to take care of such emulsions, by the addition of a fourth index figure, are quite obvious, and such extension can take place at any time that it is desirable.

Filters having the desirable property of transmitting exactly these three wavelength bands freely are not available. However, there is a considerable range of sharp cutting filters, absorbing strongly at short wavelengths and transmitting freely at long wavelengths. Such filters are available both as dyed gelatine sheets and as glass plates. There is every reason to believe that suitable filters can be obtained with adequate stability and reproducibility in both forms.

If ideal filters of this general type were available, dividing the spectrum at the limiting wavelengths decided upon, 520 millimicrons and 600 millimicrons, the test and calculation of the contribution of each portion of the spectrum would be extremely simple. For the exposure to the standard source without any additional filter, all three portions of the spectrum are present, and, designating the per cent. contribution of the three by C_b, C_g and C_r respectively, the relationship is

$$C_b + C_g + C_r = 100.$$

Using the yellow filter, absorbing at wavelengths less than 520 millimicrons, the contribution C_b would be removed. Correspondingly, the filter factor F_y, determined at density D, would be related to the contributions remaining through the relationship,

$$C_g + C_r = \frac{100}{F_y}.$$

Similarly for the red filter absorbing at wavelengths shorter than 600

millimicrons,

$$C_r = \frac{100}{F_r} .$$

Solved for the values C_b, C_g, and C_r, these equations became:

$$C_b = 100 \left(1 - \frac{1}{F_y} \right) ,$$

$$C_g = 100 \left(\frac{1}{F_y} - \frac{1}{F_r} \right) ,$$

$$C_r = 100 \left(\frac{1}{F_r} \right) .$$

It will be seen that the C's here used are related to the more complete spectral sensitivity data mentioned before through the relationships,

$$C_b = 100 \sum_{350}^{520} \frac{H_\lambda}{E_\lambda} ,$$

$$C_g = 100 \sum_{520}^{600} \frac{H_\lambda}{E_\lambda} ,$$

$$C_r = 100 \sum_{600}^{675} \frac{H_\lambda}{E_\lambda} .$$

To go from this idealized experiment to practical procedures only requires adequate approximation of the ideal by actual filters and test

TABLE I.

λ.	$T_{\lambda y}$.	$T_{\lambda r}$.
490	1.0	—
500	5.5	—
510	27.1	—
520	62.5	—
530	80.1	—
540	87.0	—
550	89.1	—
560	90.6	—
570	90.5	—
580	91.0	1.9
590	91.3	19.5
600	91.3	57.9
610	91.5	77.6
620	92.0	83.4
630	91.5	85.6
640	91.5	87.0
650	91.5	87.5
660	91.5	87.5
670	91.5	87.5

procedures. Two filters were selected by which to test the procedure. These were measured for transmission and found to have the transmission values given in Table I, $T_{\lambda y}$ and $T_{\lambda r}$ for the yellow and red filters respectively. The total radiation from the standard source transmitted by these filters was close to that of the ideal filters that they approximated. However, coefficients were introduced to correct the filter factors observed to the values which should have been obtained with ideal filters. These coefficients were obtained by calculating the ratio of the energy transmitted by the actual filters to that transmitted by the ideal filters. Using the spectral radiant intensity, J_λ, also given in Table IV, the coefficients to correct the filter factors became

$$A_y = \frac{\sum_{350}^{675} J_\lambda T_{\lambda y} \Delta\lambda}{\sum_{520}^{675} J_\lambda \Delta\lambda} = .934,$$

$$A_r = \frac{\sum_{350}^{675} J_\lambda T_{\lambda r} \Delta\lambda}{\sum_{600}^{675} J_\lambda \Delta\lambda} = .902.$$

The per cent. contributions for the radiation from the standard source in each of the three wavelength regions now become

$$C_b = 100 \left(1 - \frac{1}{A_y F_y}\right),$$

$$C_g = 100 \left(\frac{1}{A_y F_y} - \frac{1}{A_r F_r}\right),$$

$$C_r = 100 \left(\frac{1}{A_r F_r}\right).$$

Table II includes filter factors and calculated contributions for four emulsions of different types. The spectral sensitivity index given in the last column of the table was obtained from the grouping scheme shown in Table III. This classes together values of the per cent. contribution

TABLE II.

Emulsion Class.	F_y.	F_r.	C_b.	C_g.	C_r.	Spectral Sensitivity Index.
Non-Color Sensitized.....	>20	>20	100	0	0	13-0-0
Orthochromatic.....	4.3	>20	75	25	0	12-7-0
Panchromatic.....	2.2	6.1	51	31	18	11-8-6
High Red Panchromatic....	1.8	4.5	41	35	24	10-9-7

TABLE III.

For Determination of Index from Calculated Values of the C's.		Sensitivity Index.	For Calculation** Representative C.
$100 \geqslant C > 80$		13	90
80	64	12	72
64	50	11	57
50	40	10	45
40	32	9	36
32	25	8	28
25	20	7	22
20	16	6	18
16	12.5	5	14
12.5	10	4	11
10	8	3	9
8	6.25	2	7
6.25	5.0	1	5.5
5.0	0*	0	4.5
		−1	3.5
		−2	2.8
		−3	2.2
		−4	1.8
		−5	1.4
		−6	1.1

* All values between 5.0 and 0 are lumped as 0 in determination of original index values.
** In calculations, negative values of index occur at times which cannot be neglected without too great error.

in approximately $\sqrt[3]{2}$ steps, which is as fine subdivision as normally attempted in such photographic work.

The precision and value of these figures may be tested by applying them to a series of calculations. It is obvious from the derivation of the C's that they cannot represent in entirety the spectral response of the emulsions for which they have been determined. Calculations based upon these C's assume, in general, that the spectral sensitivity is even within each wavelength interval and changes abruptly at the designated limiting wavelengths. The calculations presented below show a large proportion of cases where good agreement is obtained between calculation and experiment and a rather small proportion of cases where the agreement is poor. In general, the cases of poor agreement may be traced to use of filters limiting the exposure to some region of the spectrum where actually the spectral sensitivity is changing rapidly, but in a way not shown by the C's.

Three types of calculation are considered:

(a) The calculation of filter factors, F_x, for filters, other than the original yellow and red filters, used with the standard source.

(b) The calculation of the ratio of the speed of the film, as determined with a second source, S_x, to its speed determined with the standard source, S_s.

(c) The calculation of filter factors, F_{xs}, for filters used with a second source.

The equations to be evaluated are based upon the law of additivity of photographic exposure previously mentioned. These equations could be expressed as integrals, but since any practical application would normally be made through summations of components obtained from tables of spectral radiant intensity and transmission values customarily given at 10 millimicron intervals, the summation form has been used to clearly indicate the operation contemplated.

(a) Standard source—other filters.

$$\frac{100}{F_{ss}} = \frac{\sum_{350}^{520} J_\lambda T_\lambda \Delta\lambda}{\sum_{350} J_\lambda \Delta\lambda} C_b + \frac{\sum_{520}^{600} J_\lambda T_\lambda \Delta\lambda}{\sum_{520} J_\lambda \Delta\lambda} C_g + \frac{\sum_{600}^{675} J_\lambda T_\lambda \Delta\lambda}{\sum_{600} J_\lambda \Delta\lambda} C_r.$$

(b) Speed ratio for two sources.

$$100 \frac{S_x}{S_s} = \frac{\sum_{350}^{520} X_\lambda \Delta\lambda}{\sum_{350} J_\lambda \Delta\lambda} C_b + \frac{\sum_{520}^{600} X_\lambda \Delta\lambda}{\sum_{520} J_\lambda \Delta\lambda} C_g + \frac{\sum_{600}^{675} X_\lambda \Delta\lambda}{\sum_{600} J_\lambda \Delta\lambda} C_r.$$

(c) Filter factor with second source.

$$\frac{100}{F_{xs}} \frac{S_x}{S_s} = \frac{\sum_{350}^{520} X_\lambda T_\lambda \Delta\lambda}{\sum_{350} J_\lambda \Delta\lambda} C_b + \frac{\sum_{520}^{600} X_\lambda T_\lambda \Delta\lambda}{\sum_{520} J_\lambda \Delta\lambda} C_g + \frac{\sum_{600}^{675} X_\lambda T_\lambda \Delta\lambda}{\sum_{600} J_\lambda \Delta\lambda} C_r,$$

where

J_λ represents the spectral radiant intensity of the standard source.
X_λ represents the spectral radiant intensity of the second source.
T_λ represents the spectral transmission of the filter.
S_x = speed with second source.
S_s = speed with standard source.
F_{ss} = filter factor with standard source.
F_{xs} = filter factor with second source.

For use in these equations, the units of J_λ and X_λ must be such that

$$\int J_\lambda V_\lambda d\lambda = \int X_\lambda V_\lambda d\lambda,$$

where V_λ is the visibility function of the eye.

The tables commonly available do not give the values exactly in this form. Therefore, for convenience of calculation, values are given

TABLE IV.

Wavelength, Millimicrons.	2360°.	2600°.	2800°.	3000°.	3200°.	J_λ Standard Source.
350	1.44	2.70	4.17	6.08	8.41	2.5
360	2.04	3.63	5.44	7.70	10.4	4.9
370	2.80	4.79	6.97	9.61	12.7	8.7
380	3.78	6.21	8.79	11.8	15.4	14.5
390	5.00	7.93	10.9	14.3	18.2	22.5
400	6.49	9.94	13.3	17.2	21.4	32.3
410	8.32	12.3	16.1	20.3	24.9	44.0
420	10.5	15.1	19.2	23.8	28.6	57.4
430	13.1	18.4	22.7	27.6	32.7	70.3
440	16.1	21.6	26.6	31.6	36.9	81.2
450	19.5	25.5	30.7	35.9	41.4	88.6
460	23.5	29.9	35.3	40.6	46.0	93.9
470	27.9	34.6	40.3	45.5	50.8	99.9
480	32.7	39.8	45.7	50.6	55.8	105.0
490	38.3	45.4	50.8	55.9	61.0	107.1
500	44.5	51.4	56.7	61.6	66.1	103.9
510	51.2	57.8	62.8	67.2	71.4	98.3
520	57.5	64.6	69.1	73.0	76.7	95.0
530	66.2	71.8	75.7	79.0	82.1	96.7
540	74.6	79.2	82.4	85.1	87.4	100.6
550	83.4	87.1	89.4	91.2	92.8	103.2
560	93.0	95.2	96.5	97.3	98.1	103.1
570	102.9	103.5	103.7	103.4	103.3	100.4
580	113.3	112.2	111.1	109.7	108.5	96.9
590	124.3	121.0	118.4	115.8	113.6	93.4
600	135.8	130.0	125.8	121.9	118.6	91.3
610	147.6	139.2	133.2	127.9	123.4	91.2
620	159.8	148.5	140.7	133.7	128.1	92.3
630	172.3	158.0	148.1	139.5	132.5	93.3
640	185.1	167.4	155.4	145.2	137.1	94.0
650	198.4	177.0	162.7	150.8	141.3	95.1
660	211.7	186.3	170.0	156.2	145.2	95.1
670	225.6	195.9	176.8	161.6	149.2	93.4
680	239.2	205.2	183.8	166.6	152.9	90.5
690	253.4	214.8	190.6	171.5	156.4	85.8
700	267.3	224.0	197.2	176.3	159.7	81.2
710	281.4	233.1	203.9	180.8	163.5	76.4
720	295.6	242.1	210.1	184.9	165.7	71.6

in Table IV corrected as required by the equation above. The relative spectral radiant intensity for the standard source, given in the last column of the table, is that published for the standard source in the Proceedings of the Seventh International Congress of Photography and also in the Bureau of Standards Miscellaneous Publication 114. All the correction for relative luminosity is arbitrarily thrown into the values for the other color temperatures. The values, therefore, in any one column are proportional to values in the Bureau of Standards Publication (loc. cit.), pages 21 and 22, but differ by a factor dependent upon the color temperature involved.

V.2
194

A comparison of calculated and observed values for filter factors, speed ratios and filter factors with the second source is presented in Table V. The films used were those presented in Table II. The filters

TABLE V.

Filter Factors.

Filter.	Standard Source.		2475° Source.		Speed Ratio.	
	Calc.	Obs.	Calc.	Obs.	Calc.	Obs.
Non-Color Sensitized (13–0–0)					.28	.32
12	—	>20	10	> 20		
25	—	>20	>20	> 20		
47	4.5	3.2	4.0	3.5		
58	11	>20	5.1	> 20		
2A	1.8	1.8				
Aero 1	2.8	5.9				
Aero 2	7.1	34				
Orthochromatic (12–7–0)					.44	.45
12	—	4.3	2.2	2.4		
25	—	>20	24	>100		
47	5.5	4.3	8.0	6.3		
58	6.2	7.0	4.2	4.0		
2A	1.6	1.6				
Aero 1	2.2	2.5				
Aero 2	3.4	3.8				
Panchromatic (11–8–6)					.82	.86
12	—	2.2	1.6	1.5		
25	—	6.1	2.7	2.9		
47	7.1	6.5	18.2	19		
58	6.1	6.1	6.4	5.6		
2A	1.4	1.3				
Panchromatic (10–9–7)					.95	.93
12	—	1.8	1.5	1.4		
25	—	4.5	2.4	2.1		
47	9.0	7.2	21	20		
58	5.4	5.9	6.5	5.9		
2A	1.4	1.3				

used were selected from a group of Wratten filters available, but transmission values were measured for the individual filters, rather than using the typical transmission values published. These filters are designated by their number in the Wratten listing. The second source used was tungsten lamp operated at 2475° K. Satisfactory agreement, better than one third of a stop when considered as an indication of camera exposure to be used, was obtained between calculated and observed values in all tests with panchromatic films. With the orthochromatic film and the source of lower color temperature, the filter

factor calculated for the No. 25 filter is lower than that observed. Similarly, for several of the filters, particularly the yellows, used with the non-color sensitized emulsion there is a large discrepancy between calculation and observation. In all these cases, the difference is traceable to the fact that the exposures are limited to long wavelength portions of the spectral regions involved, and the calculations can take no account of actual differences in sensitivity within these elemental regions. This represents a limitation to the application of these calculations, but leaves a large field of utility, since such degree of spectral purity is not often encountered in scenes in nature, and an experienced photographer will readily recognize the cases when such discrepancies may be expected from the nature of the emulsions and filters being used together.

In spite of the many cases where good agreement has been obtained between calculations and observations, it does not seem that the chief value of the proposed index will lie in those calculations. Its fundadental value appears to be as a simple, concise quantitative description of the spectral sensitivity of an emulsion. There are many places in photographic literature and technology where this type of designation can find a useful place.

Suggestions received from other members of the ASA subcommittee were incorporated in this proposed spectral sensitivity index as the work progressed.

REFERENCES.

1. (a) BERTLING, H.: "Direct determination of colour-sensitivity of photographic layers by spectrographs." *Phot. Ind.*, **29**: 1090–1094 (1931).
(b) BILTZ, M.: "Absolute colour-sensitivity of photographic emulsions." *Physikal. Z.*, **36**: 559–563 (1935).
(c) EDER, J. M.: "Colour-sensitivity curves." *Phot. Ind.*, **1929**: 852.
(d) FOIGE, K.: "Spectral sensitograph for recording colour-sensitivity curves of photographic coatings." *Phot. Korr.*, **71**: 50–52 (1935).
(e) FOIGE, K.: "Spectro-sensitometer for the determination of a colour-sensitive curve." *Atelier Phot.*, **42**: 130–133 (1935).
(f) GOROCHOWSKY, G., AND E. WALIASCHKO: "Spectral sensitivity of photographic plates in absolute units." *Techn. Physics USSR*, **3**: 528–540 (1936).
(g) HARVEY, E. A.: "Simple apparatus for tracing spectral sensitivity curves." *Phot. J.*, **81**: 231–234 (1941).
(h) JONES, L. A., AND O. SANDVIK: "Distribution of spectral sensitivity of photographic materials." *J.O.S.A.*, **12**: 401–416 (1926).
(i) JONES, L. A.: "Photographic sensitometry." *J.S.M.P.E.*, **18**: 324–355 (1932).
(j) KUTZLEB, L.: "Practical work with the energy leveller." *Kinotech.*, **11**: 328–331 (1929).
2. (a) ARENS, H., AND J. EGGERT: "Sensitometry with spectrum and colour chart." *Z. wiss. Phot.*, **29**: 239–261 (1930).
(b) BILTZ, M., AND J. EGGERT: "Determination of the colour sensitivity of negative materials for pictorial exposures." *Veroffentlich. wiss. Zentral-Lab. phot. Abt. Agfa*, **4**: 35–41 (1935).
(c) BÜRKI, F.: "New apparatus for the simple determination of the colour sensitivity of photographic plates and films." *Camera (Schweiz)*, **8**: 235–238 (1930).

(d) Eder, J. M.: "Conversion of Eder-Hecht wedge readings into true colour sensitiveness values." *Phot. Ind.*, **1927**: 915.
(e) Eder, J. M.: "Determination of the colour-sensitiveness of orthochromatic plates and its relation to ideal transparent filters." *Phot. Rund.*, **63**: 421–422 (1926).
(f) Eder, J. M.: "Eder-Hecht grey-wedge photometer." *Phot. Korr.*, **57**: 304–307 (1920).
(g) Eder, J. M.: "New neutral-wedge photometer for sensitometry, for photographic copying processes and scientific light measurement." *Phot. Korr.*, **56**: 244–271 (1919).
(h) Eder, J. M.: "Sensitometer with double colour scale." *Phot. Korr.*, **58**: 87 (1921).
(i) Eder, J. M.: "The sensitometry of photographic plates corrected for ideal transparent filters." *Phot. Ind.*, **1926**: 967–968.
(j) Eggert, J.: "Colour sensitometry." *Z. wiss. Phot.*, **34**: 54–58 (1935).
(k) Foige, K.: "Methods of determining colour-sensitivity." *Phot. Rund.*, **63**: 309–316 (1926).
(l) Hansen, K.: "Colour sensitometry." *Phot. Ind.*, **1921**: 76–77.
(m) Heisenberg, E., and M. Biltz: "A criticism of the Hübl system of colour sensitometry." *Phot. Korr.*, **66**: 169–176, 198–203 (1930).
(n) Hübl, A.: "Sensitivity of photographic plates to artificial light." *Phot. Ind.*, **26**: 758–759 (1928).
(o) Hübl, A.: "Sensitivity of photographic plates for the primary colors." *Phot. Ind.*, **26**: 901–902 (1928).
(p) Jacobsohn, K.: "Characterization of colour sensitiveness." *Phot. Ind.*, **1930**: 335–336.
(q) Jacobsohn, K.: "Classification of colour-sensitiveness." *Phot. Ind.*, **1929**: 295–296.
(r) Langer, E. O.: "Emulsion testing for colour sensitivity by means of a colour table." *Phot. Ind.*, **1934**: 926–929.
(s) Mecke, R., and F. Rose: "Determination of colour-sensitivities with DIN-sensitometer." *Z. Techn. Physik*, **18**: 390–393 (1937).
(t) Mendelsohn, T.: "Colour sensitivity tests with the Eder-Hecht wedge." *Phot. Ind.*, **32**: 202–203 (1934).
(u) Neugebauer, P. V.: "A new method for testing colour sensitive plates with the colour sensitometer." *Phot. Rund.*, **60**: 12–14 (1923).
(v) Nidetsky, G.: "Determination of the colour-sensitivity of photographic emulsions by means of filters." *Phot. Ind.*, **34**: 432–433, 455–457 (1936).
(w) Richter, R.: "Determination of spectral sensitivity of photographic negative emulsions." *Z. wiss. Phot.*, **36**: 251–265 (1937).
(x) Schwarz, G.: "Determination of colour sensitivity of an emulsion and of colour filter factors." *Phot. Korr.*, **68**: 23–25 (1932).
(y) Tchibissof, T., and V. Tcheltsof: "Measurement of colour sensitivity of photographic emulsions." *Kinotech.*, **13**: 320–325 (1931).
3. Van Kreveld, A.: "Standardization of photographic sensitometry based upon the addition law." *J.O.S.A.*, **29**: 327–336 (1939).
4. The Unit of Photographic Intensity. Proceedings of the Seventh International Congress of Photography, 152–161, July, 1928. (W. Heffer & Sons, Ltd., Cambridge, England.)

ARMY AND NAVY NOTES.

Coated Fabrics for Variety of Military Uses.—(*Textile World*, Vol. 93, No. 9.) The Fabrikoid Division of E. I. duPont de Nemours & Co. recently displayed equipment for our fighting men in its office in the Empire State Building, New York. The largest single use for coated fabrics, other than in tents, is in manufacture of Army raincoats. The shortage of rubber led to development of a polyvinyl acetal resin coating which permits production of a lighter coat that is better in many respects than the rubberized ones. A new Army rainsuit worn over the regular uniform consists of a duplex fabric made by cementing together two thicknesses of cotton cloth with a vinyl resin. In one type of rainsuit and hat used by Navy mine planters, the fabric is coated on both sides with a synthetic resin. Marines carry a waterproof poncho which serves as a raincape, pup-tent section, and for wrapping supplies and equipment which must be kept dry. This is made from a duplex fabric combined with a polyvinyl acetal resin.

For Arctic use, the Quartermaster Corps designed a sleeping bag, the outer shell of which is made from vinyl resin coated balloon cloth, and the kapok-filled pad from a fabric coated with polyvinyl acetal resin. A jungle hammock has a waterproof and mildew-proof canopy made from a synthetic resin coated fabric.

So-called mountain tents are made of a synthetic resin coated fabric—olive drab on one side, white on the other—for use in wooded or snow covered terrain. A portable dark room tent for fluoroscopic examinations is made from a fabric coated with synthetic rubber, and a synthetic resin is used to coat the fabric of a field shelter used for repair and maintenance of airplane motors in stormy weather.

The synthetic resin coated cotton or rayon fabric used as a utility cover and emergency sail for life rafts is colored yellow on one side for rescue identification purposes, dark blue on the other for camouflage. A second type of life raft covering is made from a light-weight Nylon fabric with synthetic resin coating. Another use for synthetic resin coated fabrics for camouflage is for covering dummies to draw enemy fire. Identification panels developed by the Signal Corps are employed to mark airplane landing fields and these are made from acetate rayon fabrics dyed in brilliant colors and coated with vinyl resin; other identification panels are coated with ethylcellulose.

R. H. O.

V.23
1944

ZEROS OF BESSEL FUNCTIONS.

BY

D. B. SMITH,* L. M. RODGERS,* AND E. H. TRAUB.*

In recent years there has been a substantial increase in practical problems requiring the solution of the general equations of mathematical physics. Where the physical configuration is circular it is, of course, convenient to employ Bessel Functions in obtaining the solution and consequently a table of Bessel Function roots is essential. Typical examples of such problems are propagation of waves in cylindrical conductors and wave guides, heat flow in cylinders, vibration of circular membranes and allied problems. In addition in the detailed design of electrically resonant cavities for uses in connection with high frequency equipment it has been necessary to obtain detailed information concerning all possible resonant modes in a given frequency band, necessitating the knowledge of all root values of Bessel functions and their first derivatives having a value less than a particular maximum depending upon the problem.

The tables which follow give the positive real roots between 0 and 25 for function and first derivative of Bessel functions of the first kind. These tables were prepared for use by the Research Division of the Philco Engineering Department.

Table I is a table of the roots of the first derivatives ($J'n$) of the functions. These roots were computed by one of three methods depending on the values of the argument and the root. For values of the argument 15 or less, and for orders seven and below, the first three roots were obtained by the method of successive approximations using elementary functional equations derived from the series solution of Bessel's equation. The values of J_0 and J_1 for this method were taken from Table I of Gray, Matthew and MacRoberts.† When values of the argument separated by .01 caused the function to change from one sign to the other, two additional places were interpolated, assuming linearity.

Higher roots, i.e., the 3rd and above, of the order to and including seven, were obtained by the M'Mahon series. The equations used were found on page 260 of Gray, Matthew and MacRobert. However, the equation for the zeros of the first derivatives as given there is incorrect, the equation given being that for the $(S + 1)$th root, and not for the Sth root as indicated there.

* Philco Radio & Television Corporation.

† "Bessel Functions."

TABLE I.

Roots of $Jn'(X_s) = 0$.

Order \ Root	1	2	3	4	5	6	7	8	9
0	0.0000	3.8317	7.0156	10.1735	13.3237	16.4706	19.6159	22.7601	25.9037
1	1.8412	5.3314	8.5363	11.7060	14.8636	18.0155	21.1644	24.3113	
2	3.0542	6.7061	9.9695	13.1704	16.3475	19.5129	22.6721		
3	4.2012	8.0152	11.3459	14.5859	17.7888	20.9724	24.1469		
4	5.3175	9.2824	12.6819	15.9641	19.1960	22.4010			
5	6.4156	10.5199	13.9872	17.3128	20.5755	23.8033			
6	7.5013	11.7349	15.2682	18.6374	21.9318				
7	8.5778	12.9324	16.5294	19.9419	23.2681				
8	9.6474	14.1156	17.7740	21.2291	24.5872				
9	10.7114	15.2868	19.0045	22.5014					
10	11.7709	16.4479	20.2230	23.7608					
11	12.8265	17.6003	21.4309						
12	13.8788	18.7451	22.6293						
13	14.9284	19.8832	23.8194						
14	15.9754	21.0154							
15	17.0203	22.1423							
16	18.0633	23.2644							
17	19.1045	24.3819							
18	20.1441								
19	21.1823								
20	22.2191								
21	23.2548								
22	24.2894								

For orders above the 7th, Taylor's series was used for all roots by taking successive approximations. The values of $J_n(x)$ for all orders for integral values of x up to 25 are given in Table II of Gray, Matthew and MacRobert. From this table all derivatives of $J_n(x)$ may be obtained.

Many of the values of the derivative roots were checked by the following method. The B.A. tables ‡ give the value of J_0 and J_1 for arguments from 0 to 25. The higher order functions can easily be computed for any of these arguments. While this process involves a division, a multiplication and a subtraction for each order of J_0 the value of even a high order function can be obtained in a relative short time, since the arithmetic is easily performed by means of a calculating machine.

Table II is a table of the roots of the Bessel functions themselves and with the exception of the first roots of the 16th through 20th orders were all calculated by the last mentioned method, taking two points for each root and interpolating.

The first roots of the 16th through 20th orders were obtained by use of the formula found on page 143 of Jahnke and Emde,§ which equation holds good only for high orders of the functions.

‡ British Association—Mathematical Tables VI.

§ "Table of Functions" third edition.

TABLE II.

Roots of $J_n(X_s) = 0$.

Order \ Root s	1	2	3	4	5	6	7	8
0	2.40483	5.52008	8.65373	11.79153	14.93092	18.07106	21.21164	24.35247
1	3.83171	7.01559	10.17347	13.32369	16.47063	19.61586	22.76008	
2	5.13562	8.41724	11.61984	14.79595	17.95982	21.11700	24.27112	
3	6.38016	9.76102	13.01520	16.22347	19.40942	22.58273		
4	7.58834	11.06471	14.37254	17.6160	20.8269	24.1990		
5	8.77142	12.33860	15.70017	18.9801	22.2178			
6	9.93611	13.58929	17.0038	20.3208	23.5861			
7	11.08637	14.82127	18.2876	21.6416	24.9349			
8	12.22509	16.0378	19.5545	22.9452				
9	13.35430	17.2412	20.8070	24.2339				
10	14.47550	18.4335	22.0470					
11	15.58985	19.6160	23.2759					
12	16.6983	20.7899	24.4949					
13	17.8014	21.9562						
14	18.9000	23.1158						
15	19.9944	24.2692						
16	21.0851							
17	22.1725							
18	23.2568							
19	24.3383							

It is believed that the tables are accurate to the extent that the last figure is within plus or minus two of the correct value. The authors wish to acknowledge their appreciation for the assistance given them by Mr. Charles Rheams, Miss Olga Yeaton and Miss Ruth Wiler.

ARMY AND NAVY NOTES.

3,000 KVA Mobile Unit Substation.—With war plants and military installations vitally dependent on the continued flow of electric power, even a temporary shut down of a distribution substation might have very serious effects. In order to prevent trouble or maintenance in permanent substations from causing long service outages, General Electric, in coöperation with the engineers of the Consolidated Gas, Electric Light and Power Company of Baltimore, has built a complete 3,000 KVA mobile unit substation, which is ready at a moment's notice to be moved to any part of the system where emergency power is required.

This equipment is one of the largest ever built for highway use, having a capacity sufficient to supply enough power for a small town. The complete substation includes the power transformer, high-voltage fuses and disconnecting switches, feeder oil circuit breaker, lightning arresters for both high and low voltage circuits, and load ratio control equipment to regulate the low voltage under load. Weighing 20 tons, the substation is compactly mounted on a semitrailer, the front end of which is supported by the towing tractor during transportation.

This equipment can be used to transform power circuits of 33,000 or 13,200 volts on the high voltage side and circuits of 2450, 4400, 7620 or 13,200 volts on the low voltage side. It can be used on any of approximately 60 permanent substations on the customer's system, to increase their power output or as a substitute if emergency conditions shut down one of the regular substations.

V.2
1944

The transformer section is of the forced oil, forced air cooled type with directed flow, making it unusually small in size, with considerable saving in weight and critical materials. The 2-fan cooler is mounted at the front of the trailer, in a vertical position, with the fans and circulating pumps in back. In order to permit rapid selection of the unit substation voltages to match the circuit voltages before placing the equipment in service, both high voltage and low voltage series multiple switches are provided and arranged for operation by convenient external hand wheels. For maximum flexibility of application, the high voltage windings are provided with regulating taps, which can be changed by an externally operated ratio adjuster when the unit is deënergized.

The outstanding features of this mobile substation are its completeness and the ease with which it can be placed in service. The fuses and arcing horns are the only parts that are removed during transportation. Upon arrival at the site, the fuses and arcing horns are installed, the proper circuit connection is chosen by turning the hand wheels brought out the side of the case, the operating mechanisms are unlocked, connections are made to the power lines, and the substation is ready for service.

R H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

SURGE CURRENT GENERATOR.

The Bureau has just completed the construction of a surge current generator in its high-voltage laboratory. The primary purpose is to make possible a study of the methods used in measuring transient currents of short duration and large magnitudes. The new equipment consists of 80 capacitors, each of 1 microfarad, and capable of being charged to 25,000 volts. The total stored energy is therefore 50,000 joules. When the capacitors are connected four in series, as is usually the case, they can be charged to 100,000 volts. The inductance of the discharge circuit when no external impedance is used is only 1.6 microhenries so that the crest value of the oscillatory discharge current exceeds 200,000 amperes. When resistors are used to damp the discharge and obtain an approximation to the wave form of a typical lightning stroke, the current is reduced to about 1/3 of this value. The equipment will also prove useful in studying methods for testing lightning arresters and other problems involving large transient currents. Its construction has been pushed to completion at the present time because such a surge generator has been needed for a lightning protection study requested by the armed services. It is expected that the techniques for the measurement of these transient currents with reasonably high precision can be developed in the future.

STANDARD FREQUENCY BROADCAST SERVICE.

On February 1, 1944, two changes were inaugurated in the Bureau's standard frequency broadcast service. One was the addition of a new radio frequency, 2,500 kilocycles per second, at night; the other, the omission of the pulse on the 59th second of every minute. The service, which is continuous at all times, day and night, from 10-kilowatt transmitters, now includes: (1) standard radio frequencies, (2) standard time intervals accurately synchronized with basic time signals, (3) standard audio frequencies, (4) standard musical pitch, 440 cycles per second, corresponding to A above middle C.

At least three radio carrier frequencies are on the air at all times, to insure reliable coverage of the United States and other parts of the world. The radio frequencies are:

2.5 megacycles (= 2,500 kilocycles = 2,500,000 cycles) per second, broadcast from 7:00 P.M. to 9:00 A.M. EWT (2,300 to 1,300 GMT).

* Communicated by the Director.

5 megacycles (= 5,000 kilocycles = 5,000,000 cycles) per second, broadcast continuously day and night.

10 megacycles (= 10,000 kilocycles = 10,000,000 cycles) per second, broadcast continuously day and night.

15 megacycles (= 15,000 kilocycles = 15,000,000 cycles) per second, broadcast from 7:00 A.M. to 7:00 P.M., EWT (1,100 to 2,300 GMT).

Two standard audio frequencies, 440 cycles and 4,000 cycles per second, are broadcast on the radio carrier frequencies of 5, 10, and 15 megacycles. The audio frequency 440 cycles only is broadcast on 2.5 megacycles. The 440 cycles is the standard musical pitch, A above middle C; the 4,000 cycles is a useful standard audio frequency for laboratory measurements.

In addition, on all carrier frequencies a pulse of 0.005-second duration occurs periodically at intervals of precisely one second. The pulse consists of 5 cycles, each of 0.001-second duration, and is heard as a faint tick when listening to the broadcast; it provides a useful standard of time interval, for purposes of physical measurements, and may be used as an accurate time signal. On the 59th second of every minute the pulse is omitted.

The two audio frequencies are interrupted precisely on the hour and each 5 minutes thereafter; after an interval of precisely 1 minute they are resumed. This 1-minute interval is provided in order to give the station announcement and to permit the checking of radio-frequency measurements free from the presence of the audio frequencies. The announcement is the station call letters (WWV) in telegraphic code (dots and dashes), except at the hour and half hour when a detailed announcement is given by voice.

The accuracy of all the frequencies, radio and audio, as transmitted, is better than a part in 10,000,000. Transmission effects in the medium (Doppler effect, etc.) may result in slight fluctuations in the audio frequencies as received at a particular place; the average frequency received is, however, as accurate as that transmitted. The time interval marked by the pulse every second is accurate to 0.000 01 second. The 1-minute, 4-minute, and 5-minute intervals, synchronized with the seconds pulses and marked by the beginning or ending of the periods when the audio frequencies are off, are accurate to a part in 10,000,000.

The beginnings of the periods when the audio frequencies are off are so synchronized with the basic time service of the U. S. Naval Observatory that they mark accurately the hour and the successive 5-minute periods.

Of the radio frequencies on the air at a given time, the lowest provides service to short distances, and the highest to great distances. Reliable reception is in general possible at all times throughout the United States and the North Atlantic Ocean, and fair reception throughout the world.

Information on how to receive and utilize the service is given in Letter Circular LC731, "Methods of Using Standard Frequencies Broadcast by Radio," obtainable on request. Reports of difficulties, methods of use, or special applications of the service are welcomed; correspondence should be addressed National Bureau of Standards, Washington, D. C.

EFFECT OF BRONZE ON MARBLE.

On account of the unsightly staining of marble by bronze statuary and the fact that marble so stained appears to disintegrate more rapidly than it should, some exposure tests were started 5 years ago to determine the effects of 3 different bronze compositions on 1 particular calcitic marble. One point in question was whether the dark brown discolorations that frequently occur so prominently on such structures as the Grant Memorial in Washington are caused by bronze.

The specimens consisted of bars of marble 18 inches long and $4 \times 1\frac{1}{2}$ inches in cross section, with bronze boxes in the middle containing 1.800 grams of bronze shavings. One face of the marble slab formed the bottom of each box, the top of which was open to allow rain water to leach downward through the shavings and spread over the marble. The slabs were supported at the ends and attached to the north coping of a building. Fifteen marble control specimens without bronze in contact were similarly exposed.

Flexural strength, abrasive hardness, absorption, porosity, and bulk density determinations were made on the marble before exposure, and the same tests were repeated after five years.

The marble shows two types of discoloration: (1) prominent dark brown on the tops of slabs adjacent to the bronze boxes, (2) brilliant green stains on the bottoms of slabs and also on the tops, where covered by bronze. Probably the green stains are caused by the formation of copper carbonate, whereas the brown stains result from the action of copper solutions on the pyritic impurities, changing the pyrite to chalcopyrite. It seems that a direct exposure to sunlight is necessary for the formation of the brown discolorations.

All specimens showed a decrease in flexural strength, the control specimens losing about 11 per cent., and the bronze exposure a maximum of 14 per cent. Abrasive hardness increased somewhat for the control specimens, and more for those exposed to bronze. Absorption values increased slightly for the control specimens and all but one of the bronze exposures. There were slight decreases in bulk density for all specimens.

The above comments apply only to untreated marble specimens. The producer who supplied the marble for this study applied a pore sealing treatment to one set of specimens, and these were exposed to the three bronze compositions as described above. These specimens

were not stained appreciably, but they showed marked losses in strength and resistance to abrasion.

MACRO ANALYSIS OF CARBON AND HYDROGEN.

During the past 15 years, several investigations at the Bureau have involved analyses of carbon and hydrogen. Each of these investigations incorporated in its apparatus such prior improvements as were appropriate, and made some new contributions to the problem. A note (RP1577) by D. D. Wagman and F. D. Rossini in the March *Journal of Research* describes the present state of development of an analytical combustion apparatus for the accurate determination on a macro scale of carbon and hydrogen in hydrocarbons or in compounds containing carbon, hydrogen, and oxygen. The precision and accuracy attainable with this apparatus are indicated by the results of a series of 5 experiments performed on highly purified benzoic acid. Two illustrations are included, one giving the assembly of the apparatus as used for nonvolatile liquids or solids, and the other giving details of the construction of the tube for the main reaction of combustion and of the combustion tube for the purification of the oxygen.

V.2
194

SALTS OF GALACTURONIC ACID.

Although galacturonic acid in the form of pectic substances comprises a large part of the cell framework and skeletal structure of plant tissues, satisfactory methods have not heretofore been available for its separation from the liquors obtained by hydrolysis of plant materials. Horace S. Isbell and Harriet L. Frush have now made a detailed study of the salts of galacturonic acid with the object of discovering a difficultly soluble salt suitable for separating the acid from plant materials, as for example from the pulp which remains after separation of sugar from sugar beets. The results of their investigation will be published as RP1576 in the March *Journal of Research*. In the course of the work, crystalline salts of potassium, ammonium, cadmium, silver, calcium, and strontium have been obtained. In addition, a unique type of double salt containing both a monovalent and a divalent metal has been discovered. As representatives of this class, crystalline sodium calcium, sodium strontium, sodium barium, sodium cadmium, sodium lead, and potassium calcium galacturonate have been prepared. The double salts are particularly useful for separating galacturonic acid from the liquors obtained by the hydrolysis of pectic materials. The existence of a simple method for isolating galacturonic acid should lead to a rapid development in the study and application of this abundant raw material.

Studies of the changes in optical rotation which follow dissolution of the salts in water show that they establish equilibrium states like

that of *D*-galactose. The freshly dissolved salts of sodium, potassium, ammonium, cadmium, and silver give mutarotations like that of *β*-*D*-galactose and hence it is concluded that they have the beta pyranose configuration. The calcium, strontium, sodium calcium, sodium strontium, sodium barium, sodium cadmium, sodium lead, and potassium calcium salts give mutarotations like that of *α*-*D*-galactose and hence they have the alpha pyranose configuration.

BUFFERS AS SPECTRAL FILTERS FOR THE ULTRAVIOLET.

Just as colored glass and gelatin filters are used to cut off certain portions of the visible and near ultraviolet regions of the spectrum, it may be feasible to employ layers of solutions of organic and inorganic compounds that are cheap, stable, and easily replaceable, in the making of spectral filters needed in photographic and spectrographic work, in the study of photochemical reactions and of excitations giving fluorescence and Raman spectra, and in ultraviolet therapy.

As part of their project on indicators for use in pH standardization, Elizabeth E. Sager, Marjorie Schooley, Alice Skelton, and S. F. Acree investigated the ultraviolet transmittancies of different concentrations of over 100 compounds of many types in acid, alkaline, and neutral solution. The primary object was to determine which substances can be used as buffers for indicators or other compounds in studies of the ultraviolet spectral region 200 to 400 mu. Most of the compounds have well defined absorption bands in the ultraviolet, the cut-off positions of which are controlled not only by the pH of the solution and the position of the first band nearest the visible, but by the concentration and thickness of the layer of solution through which the light passes. The relao tions already developed between the chemical structures and the posiioos and magnitude of the absorption index bands make it possible to chten-compounds to fill any missing gaps.

In a forthcoming paper, now being prepared, some of the buffers that have closely spaced cut-offs (5 to 20 millimicrons apart) between 200 and 400 mu will be shown on a graph. The lowest concentration in which a buffer is usually effective as a pH standard is about 0.01 molar. For that reason most of the curves shown in the figure are for solutions of that concentration. All were measured in absorption cells 1 cm. in thickness. The concentrations of many of the solutions can be so chosen that only certain segments of the ultraviolet spectrum may be cut out, thus leaving a transmission of 50 per cent. or so on both sides of the dark region for use in spectrophotometric measurements or other studies with ultraviolet light. The compounds are also being studied in lower concentrations where the absorption indexes of 1, 2, or 3 main bands may be measured accurately, the effect of changes in pH studied, and the ionization constant calculated. This information will also

contribute much to our knowledge of the electronic structure and resonance of organic compounds, of their chemical and physical properties, and of their reactions with other substances.

MECHANICAL PROPERTIES OF METALS AND ALLOYS.

Circular C447, released a short time ago, summarizes the results of a comprehensive survey of the technical literature on the strength and related properties, thermal expansion, and thermal and electrical conductivities of ferrous and non-ferrous metals and alloys at normal, high, and low temperatures. In general, the data are presented in tabular form, although graphical representation is often used to indicate the effects of changing composition or conditions on the properties. Data on aluminum, copper, iron and steel, lead, magnesium, nickel, tin, zinc, a number of miscellaneous metals, and their alloys are included. The circular, which replaces C101 and supplement, is not limited to conventional engineering materials but contains data on the properties of many materials which are not usually classed as such. References to the sources of the data are included.

Copies of C447 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. The price is $1.50.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING, MARCH 15, 1944

When the guests were assembled in the lecture hall, the National Anthem was played.

Mr. Charles S. Redding, President and Presiding Officer, then called the meeting to order and stated that the minutes of the meeting for January had appeared in the February JOURNAL of the Institute and that if no corrections were offered they would stand as printed.

On motion duly seconded and carried they were so approved.

Mr. Redding then introduced Mr. Morris Wister Wood who made an appeal to the audience to support the Red Cross Drive and made many convincing statements, calling to mind the vast amount of good being done by this organization.

The Secretary of The Franklin Institute, Dr. Henry Butler Allen, was then called upon to give his monthly report. He stated that the following additions have occurred in the Membership Department during the past month:

Sustaining	2
Active	82
Associate	28
Student	19
Library Sustaining	2
Total	133
Total Membership is now	5,797

Dr. Allen then announced the proposed programme for Medal Day and urged that members and their friends make a note of the date, Wednesday, April 19th, and that they attend this very interesting annual function. He pointed out that because of the capacity of the hall, it would be necessary this year to limit attendance at the dinner and requested everyone to send in early acceptances.

The Chairman also emphasized the importance of Medal Day and urged members of the Institute to be present.

He then introduced the speaker of the evening, giving an interesting account of some personal happenings in the life of Dr. Swann.

The meeting was then turned over to Dr. W. F. G. Swann, Director of the Bartol Research Foundation of The Franklin Institute, who spoke on "Certain Applications of Physical Principles to the Playing of Musical Instruments."

The lecture dealt with simple applications of physical principles to certain matters pertaining to musical instruments and their use. Among other things, it dealt with the question of steel versus gut strings on stringed instruments; the problem of the pressure of the bow on stringed instruments; the significance of carrying power; the question of piano tone; and certain psychological and physical principles in relation to stringed instrument technique, as in the staccato.

The talk was illustrated by lantern slides and demonstrations on the appropriate musical instruments.

The meeting adjourned at 10:30.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, March 8, 1944.)

HALL OF THE COMMITTEE,
PHILADELPHIA, MARCH 8, 1944.

MR. WILLIAM B. COLEMAN *in the Chair.*

The following reports were presented for final action:

No. 3125: SR-4 Strain Gage.

This report recommended the award of an Edward Longstreth Medal to Edward E. Simmons, Jr., of Pasadena, California, "In consideration of his development of a strain gage involving the use of fine wire, bonded to the surface under investigation by means of plastic, whereby the change in length is readily measured by the change in electrical resistance of the wire, which device has come into wide-spread use as an engineering tool."

No. 3135: Clamer Medal.

This report recommended the award of a Francis J. Clamer Medal to Walther Emil Ludwig Mathesius, of Geneva, Utah, "For his long continued, sound and beneficial influence on the development of metallurgy of iron and steel, and particularly for his contributions in the field of blast furnace practice."

No. 3136: Levy Medal.

This report recommended the award of a Louis Edward Levy Medal to Stephen P. Timoshenko, of Stanford University, California, for his paper on "The Theory of Suspension Bridges," which appeared in the March and April 1943 issues of the JOURNAL OF THE FRANKLIN INSTITUTE.

V.2
194

At the February 9, 1944, Stated Meeting, the following reports were presented for final action:

No. 3116: Resonance Transformer.

This report recommended the award of a John Price Wetherill Medal to Willem Fredrik Westendorp, of Schenectady, New York, "In consideration of his development of a successful high-voltage, low-frequency resonance transformer, of relatively small size and light weight, which is shock-proof, efficient in operation and particularly suitable for use in the high voltage portable x-ray units."

No. 3123: Air Mail and Glider Pick-Up and Delivery System.

This report recommended the posthumous award of a John Price Wetherill Medal to Richard C. duPont, of Wilmington, Delaware, "In consideration of his development of a successful and practical 'on-the-wing' air mail and glider pick-up apparatus."

These recommendations were advertised in the February issue of the JOURNAL OF THE FRANKLIN INSTITUTE.

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat prints of any material in the collections can be supplied on request. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays from two until ten o'clock P.M.

RECENT ADDITIONS.

AERONAUTICS.

JORDANOFF, ASSEN. Power and Flight. 1944.
NELSON, WILBUR C. Airplane Propeller Principles. 1944.
PETERSON, ROSS A., AND RAYMOND E. ERICKSON. Basic Aircraft Construction. 1943.
SMITH, G. GEOFFREY. Gas Turbines and Jet Propulsion for Aircraft. 1944.

AUTOMOTIVE ENGINEERING.

DENHAM, ATHEL F. 20 Years' Progress in Commercial Motor Vehicles (1921–1942). No date.

BIBLIOGRAPHY.

Union List of Serials in Libraries of the United States and Canada. Second Edition. 1943.

CHEMISTRY AND CHEMICAL TECHNOLOGY.

DREHER, EMIL. The Chemistry of Synthetic Substances. 1943.
Emulsion Technology. 1943.
HOUBEN, J. Die Methoden der organischen Chemie. Dritte Auflage. Vierter Band: Spezieller Teil. 1941.
MATTIELLO, JOSEPH J. Protective and Decorative Coatings. Volume 4. 1944.
Plastics Catalogue. 1944.
SCHMIDT, CARL L. A., Editor. The Chemistry of the Amino Acids and Proteins. Second Edition. 1944.

DIRECTORIES.

Thomas' Register of American Manufacturers 1944. Thirty-fourth Edition. Volumes 1–2. 1943.

ECONOMICS.

New York State Joint Legislative Committee on Industrial and Labor Conditions. The American Story of Industrial and Labor Relations. 1943.

ELECTRIC ENGINEERING.

American Radio Relay League. The Radio Amateur's Handbook. 21st Edition 1944. 1943.
SAMUELS, M. M. Power Unleashed. 1943.

ENGINEERING.

American Institute of Bolt, Nut and Rivet Manufacturers. Bolt, Nut and Rivet Standards. 1941.
CHASE, HERBERT, Editor. Handbook on Designing for Quantity Production. 1944.
EWING, SCOTT. Soil Corrosion and Pipe Line Protection. 1938.
LEADERMAN, HERBERT. Elastic and Creep Properties of Filamentous Materials and Other High Polymers. 1943.

MILITARY ENGINEERING.

Military Service Publishing Company. Seacoast Artillery. 1944.

MINING AND METALLURGY.

American Institute of Mining and Metallurgical Engineers. Transactions. Iron and Steel Division. 1943.
TEICHERT, ERNEST J. Ferrous Metallurgy. Volumes 1–2. Second Edition. 1944.

NAVIGATION.

BROUWER, DIRK, FREDERICK W. KEATOR, AND D. A. MCMILLEN. Spherographical Navigation. 1944.
GATTY, HAROLD. The Raft Book. 1943.

PATENTS.

U. S. Patent Office. Index of Patents 1943. 1944.

PHOTOGRAPHY.

American Annual of Photography 1944. Volume 58. 1943.
Photograms of the Year 1944.

PHYSICS.

American Committee on Annual Tables. Annual Tables of Physical Constants. 1941 and 1942.
BLAIR, G. W. SCOTT. A Survey of General and Applied Rheology. 1944.
FREEMAN, JOHN R. Experiments upon the Flow of Water in Pipes and Pipe Fittings. 1941
SPINK, L. K. Principles and Practice of Flow Meter Engineering. Sixth Edition. 1943.

SUGAR.

GILMORE, A. B., Editor and Publisher. The Puerto Rico Sugar Manual. 1942–1943. 1944

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

An Apparatus for Grinding Small Samples of Brain Tissue.—H. M. TERRILL AND D. W. MCKINSTRY. Various devices have been designed for the homogenization of small quantities of animal tissue. Potter and Elvehjem (*Journal of Biological Chemistry*, **114**: 495, 1936) describe a motor-driven glass pestle fitted to a pyrex test tube, and a somewhat similar apparatus is mentioned by Corper and Cohn (*Journal of Laboratory and Clinical Medicine*, **21**: 428, 1936). The commercially available colloid mills are not suitable for use in cases where small quantities are involved.

For grinding brain tissue, especially mouse brain tissue, several modifications have been found desirable. Since the material is more viscous, slower speeds with greater power are preferable. The glass pestles are fragile and, because of difficulties in construction, seldom run true, causing frequent breakage which involves great danger when grinding infected tissue. These disadvantages may be obviated by making the pestle of metal. It may be turned to shape in a lathe from a piece of stainless steel and when held in an accurate chuck, such as that of a small drill press, will run true throughout its length. The drill press is ideal for rotating the pestle because it provides sufficient power for thorough grinding at low speeds, thereby avoiding local heating.

Ordinarily, a little sterile water is added to the material before grinding. Where special precautions are necessary to avoid heating, it may be found advisable to chill both tube and pestle in a refrigerator before using. In some cases, sterile crushed ice may be added to the material being ground.

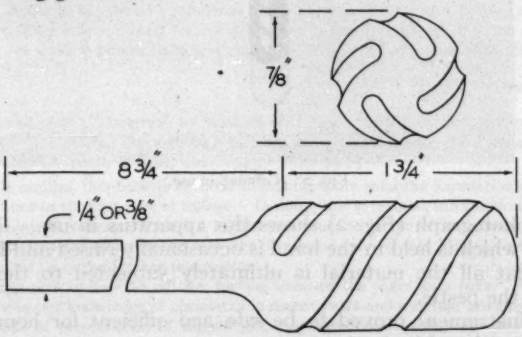


FIG. 1. Steel pestle.

Features of a pestle which has been found satisfactory are shown in Fig. 1. The grooves are shallow and rounded in section. The shape illustrated is important, for on this depends much of the grinding action. It will be noticed that the spirals run in such direction that when the pestle is rotated, the grooves tend to force the material downward.

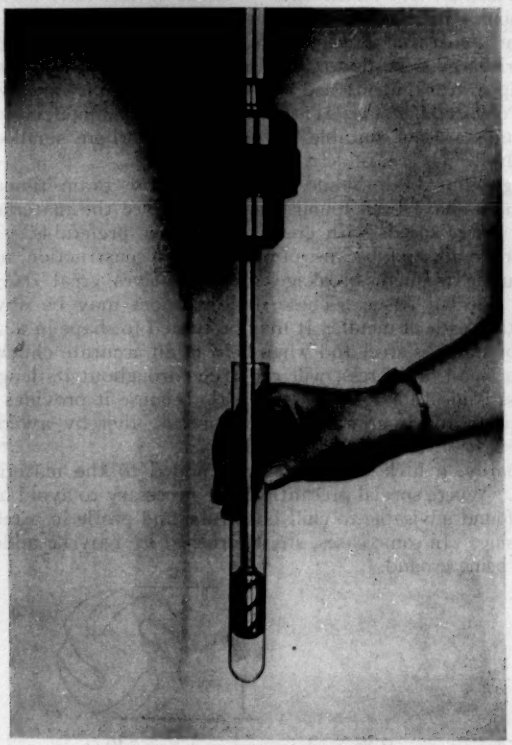


FIG. 2. Grinder in use.

The photograph (Fig. 2) shows the apparatus in use. The pyrex test tube which is held in the hand is occasionally raised and lowered to ensure that all the material is ultimately subjected to the grinding action of the pestle.

This instrument proved to be safe and efficient for homogenizing small quantities of brain tissue.

BOOK REVIEWS.

INTERMEDIATE DIFFERENTIAL EQUATIONS, by Earl D. Rainville. 213 pages, illustrations, 13 × 21 cms. New York, John W. Wiley & Sons, Inc.; London, Chapman and Hall Limited, 1943. Price $2.75.

The distinct line separating practical applied mathematics and pure mathematics is ever growing more vague. That which can be learned about differential equations, which are encountered in applied mathematics so often, is also of interest in pure mathematics as a topic itself and as a source of contacts with other branches of mathematics. This diffusion is interesting, yet there must be a definite separation especially for practical users such as engineers, physicists, chemists, etc. In the book at hand, the author takes this into consideration and has presented a book which is for the practical but does not neglect to point out topics of importance in the classical theory.

As the title implies the course laid out here is intended to bridge the gap between elementary courses and really advanced courses, and to bring into play certain mathematical tools which are useful in the solution of linear ordinary differential equations. The work opens by considering a series of elementary attacks on solving linear differential equations of the second order by using the procedure to obtain various equations equivalent to the original problem. Following along this path is a treatment of another form of equivalent, the Ricatti equation, and still later the use of power series. In taking up the latter, certain fundamental ideas and facts of the theory of functions of a complex variable are considered. This is confined to a descriptive account of elementary portions which are used farther on in the text. Under the heading of Solution in Series there is developed a reasonably good technique for actually carrying out the solution of numerical problems. Subsequent headings are Equations of Fuchsian Type, The Hypergeometric Equation, Confluence of Singularities, Whittaker's Confluent Hypergeometric Equation.

The latter part of the book is devoted to a brief account of several ordinary linear differential equations which have been studied extensively in mathematical literature. They play important roles in both pure and applied mathematics and are tools for the solution of many problems in engineering, physics and statistics. And finally there is reference to applications which lead to the study of some of the differential equations in preceding chapters. There is a subject index at the end.

The book should be of interest to students of the sciences at that point in their educational program where there exists a need for certain tools, naturally omitted in most elementary courses, which are used to connect the first course in differential equations with the advanced courses.

R. H. OPPERMANN.

SECOND YEAR COLLEGE CHEMISTRY, by William H. Chapin. Fifth edition, revised by Luke E. Steiner. 575 pages, illustrations, 14 × 22 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1943. Price $3.75.

As the title implies, this book is devoted to making more solid the foundation of chemical knowledge laid out in the first year of college. In doing this it restates fundamental principles in more of a quantitative way. This is a logical procedure to follow—from purely descriptive to the more detached and exact treatment—the particular value of which lies equally as much in the restatement as in the further progression.

This book is now in its fifth edition, having spanned the years from 1922. A great deal has taken place in our knowledge of chemistry in recent years and a similar advance has taken place in methods of presentation of the subject. A testimonial to the first and succeeding editions, is the one at hand which reflects both factors over the years. While the general out-

line seems the same, there are many changes within the chapters and pages. The structure of matter is first discussed out of which come the gas laws and liquids. Chemical combination is described, atomic weights, valence and the chemical bond. There the modern periodic arrangement is covered. At this point there is introduced a discussion on rays from vacuum tubes and radioactivity in which series are pointed out unstable elements emitting α or β particles to become new elements with new nuclear composition. This is the essence of modern transmutation which has a very interesting story here.

Solutions is the next subject considered, first the general properties and laws which include aqueous solutions, then some of the special properties of aqueous solutions. Other subjects covered in the latter part of the work are homogeneous equilibrium, neutralization indicators and acid-alkali titrations, heterogeneous equilibrium, colloids, and electrochemistry.

A good illustration of the flexibility of this work is shown in the mathematical derivation of formulas which is in small type and can be left out or included at will according to the desires of the instructor. The appendix contains 165 problems which are a great aid in facilitating understanding as well as impressing the subject matter. The subject index in the back as well as the markings of chapter numbers in the corner of each page throughout the book make for a quicker and therefore more valued reference work. The many references cited provide opportunities for a broader knowledge by the student.

As a text this later edition is modern in every respect for college work. Others, who have a good descriptive knowledge of the fundamentals of chemistry, can use this text profitably.

R. H. OPPERMANN.

THE PHYSICAL CHEMISTRY OF ELECTROLYTIC SOLUTIONS, by Herbert S. Harned and Benton B. Owen. 611 pages, tables and illustrations, 15 × 24 cms. New York, Reinhold Publishing Corporation, 1943. Price $10.00.

The knowledge of ionic solutions in the past fifty years has increased immensely. In the earlier years many attempts were made to deduce a theory of interionic attraction which must play an important role in determining the properties of such solutions. After Debye's formulation of the interionic attraction theory in 1923, a large literature developed which includes theories of all the properties of electrolytic solutions. The authors of the book at hand are convinced that the interionic attraction theory is sufficiently well established to permit the development of the purely theoretical aspects of the subject before the discussion of the experimental methods and properties. That is the basic plan of this work.

At the outset a statement is made briefly of those general conclusions of thermodynamics which provide the formal method of treating systems in equilibrium. This leads to the fundamental theory necessary for the treatment of the dynamics of ionic atmospheres. This, with the addition of further important concepts gives information for the deduction of exact equations for use in computing dilute electrolytic solutions, relating to viscosity, conductions and diffusion. A complete treatment of this theory is not given but a review is made of the fundamental physical foundations and an outline is presented of the important steps of the deductions. After this the effects of frequency and of high electrical fields upon conductance are given consideration. As a unique feature, there is a collection of the final equations resulting from the interionic attraction theory, reduced to forms suitable for practical applications.

What may be termed the second part of the book, undertakes the utilization of the experimental methods which have proved most fruitful in this field, considering first the conductance measurements, and then the measurements of thermodynamic properties in suitable order. No apparatus or experimental technique is described in detail.

The third and last part of the book covers the properties of electrolytes rather than the methods by which they were obtained. First the properties of hydrochloric acid in solutions is taken up, followed by strong 1-1 electrolytes in aqueous solution, and polyvalent electrolytes. Thermodynamic properties, their interpretation, and special theories of these solutions are discussed. The latter part of the text deals with mixtures of strong electrolytes in water; and

ionization constants of weak electrolytes, their temperature, coefficients, and the ionization of weak electrolytes in salt solutions.

The appendix contains a fund of information in the form of tables. The author index is indicative of the great number of references to the work of others, and the subject index adds greatly to the work for reference purposes.

The book is an authoritative resume of the state of the subject. An American Chemical Society Monograph, it stands alongside of other works of this nature in pointing the way to a more complete knowledge of the subject covered.

R. H. OPPERMANN.

INORGANIC CHEMISTRY, by Fritz Ephraim. English edition by P. C. L. Thorne and E. R. Roberts. 921 pages, illustrations, 16 × 24 cms. London and Edinburgh, Gurney and Jackson, 1943. Price 28 shillings.

This very fine work, which is now in its fourth edition, is not at all the type of inorganic chemistry textbook to which we are accustomed. It is not merely an amplified reference list of inorganic compounds but is rather a truly theoretical study of the background of inorganic chemistry.

The general scheme, so successful in earlier editions, has been retained in the present work. The chief section headings are:

1—Elements
2—Halogen compounds
3—Oxides of hydrogen and of the metals
4—The compounds of sulphur, selenium and tellurium
5—The nitrogen, phosphorus, arsenic group
6—The elements of the fourth group (and boron).

The materials of inorganic chemistry are dealt with collectively rather than individually, which results in making the book very convenient for the reader.

Formulation of compounds is strictly according to modern structural ideas, considerable use being made of electron formulae.

In the opinion of the reviewer, this book is one of the outstanding works on inorganic structural theory and is a valuable addition to the library of the chemist.

G. S. GARDNER.

PUBLICATIONS RECEIVED.

Dynamical Analogies, by Harry F. Holson. 196 pages, illustrations, 14 × 22 cms. New York, D. Van Nostrand Company, Inc., 1943.

The Chemistry of Synthetic Substances, by Dr. Emil Dreher. 103 pages, tables, 14 × 22 cms. New York, The Philosophical Library, 1943. Price $3.00.

Today's Geometry (Revised Edition), by David Reichgott and Lee R. Spiller. 400 pages, photographs, drawings and illustrations, 16 × 24 cms. New York, Prentice-Hall, Inc., 1944. Price $1.96.

Modern Turbines, by Louis E. Newman, Allen Keller, John M. Lyons and Lawrence B. Wales. 175 pages, photographs and charts, 15 × 22 cms. New York, John Wiley and Sons, Inc., London, Chapman & Hall, Limited, 1944. Price $2.75.

The Constituents of Wheat and Wheat Products, by C. H. Bailey. 332 pages, tables and illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1944. Price $6.50.

Illustrated Technical Dictionary, Edited by Maxim Newmark. 351 pages, illustrations, 16 × 23 cms. New York, The Philosophical Library, 1944. Price $5.00.

CURRENT TOPICS.

ARMY AND NAVY NOTES.

Recording Spectrophotometer Aids in Deceiving Enemy Observers.—General Electric's recording spectrophotometer is playing a vital role in helping our fighting forces to deceive enemy observers. The instrument is being used to match camouflage colors so they cannot be detected by the enemy's infrared cameras.

Camouflaging, an art which depends on the use of color, suffered a major set back when the infrared camera was developed. Infrared light, which is not visible to the human eye, can be photographed on a special film. Thus, two objects which, to the eye, have the same color, may photograph differently with the special film, due to different amounts of infrared received from them. This means that the camouflage artist cannot judge from the appearance of a color how it will look to the infrared camera.

But the G.-E. spectrophotometer, an electronic machine, has now come to the aid of the camouflager. It gives him a measure of color—both visible and invisible—which puts him on an equal footing with the infrared camera. For by determining the amount of light of infrared wave-lengths that is reflected by any paint or other material he wants to use, he can tell what effect that material or color will have on the plate of the infrared camera.

The spectrophotometer is indispensable in the visible range, because it insures perfect matching of colors under all conditions. Colors which appear to the eye to be perfectly matched under one light may actually be mismatched under another light. But matches made with the spectrophotometer are identical under all lighting conditions. Hence for many manufacturing processes where extremely accurate color matching is required, such as in making textiles, dyes, and paints, the spectrophotometer is a valuable aid.

R. H. O.

Gyro Flux Gate Compass.—(*Automotive and Aviation Industries*, Vol. 89, No. 9.) An entirely new type of compass is in production at the Philadelphia Division of Bendix Aviation Corporation. Developed in the research laboratories of the Eclipse-Pioneer Division of the Corporation, the new device is said to be as great an advance over the conventional magnetic compass as that compass over the lodestone.

This Gyro Flux Gate Compass, as the new compass is known, uses the earth's magnetic field to develop minute electrical impulses which, when amplified, turn the compass indicator.

This new compass will not go off its reading when the plane dives or climbs rapidly, it will not lag or overshoot during a turn and it will not oscillate or "hunt" back and forth in rough weather.

An advantage of the new compass is that no "correction card," necessary with magnetic types, is needed because it gives fully corrected readings at all times. The possibility of the navigator or pilot making an error in the heat of battle is thus eliminated.

Because it is possible to locate the transmitter of this new compass at a distance from the indicating dial, it is possible to find a position for it where it will not be affected by the bomb load, armor plate, or other metal parts that impair the accuracy of the standard compass. Additional indicators are linked to the compass through the medium of the Pioneer "magnesyn" system. This system makes possible remote readings of indications or measurements received from a remote source or master.

R. H. O.

Blimps Blast Subs.—R. G. PICINICH, JR. (*United States Naval Institute Proceedings*, Vol. 69, No. 488.) The work of airships in helping to curb the submarine attacks last year was so impressive that a bill was presented to Congress and passed authorizing the construction of 48 of the lighter than air craft. Even before these ships were all delivered, their performance exceeded previous expectations. Congress was again called on, and in June 1942, a bill was passed empowering the Navy to construct 200 airships.

The worth of the blimp was not fully understood or appreciated until the vehicle was used in convoy duty. In coöperation with planes and surface vessels, the blimps have been successful in bagging many subs. Last August, Admiral Karl Doenitz, Germany's U-boat chief, made a speech about the hazards of submarine operation on the eastern seaboard and mentioned the blimp as an especial danger to the U-boat.

When it comes to stalking undersea boats, the blimp has been found to have advantages over both the airplane and the surface craft. Unlike the plane, it can point its nose into the wind, cut its motors, and hover over one spot for hours. It can dart here and there over a convoy at twice the speed of a destroyer. It forms a steady platform from which bombs can be dropped accurately without use of intricate bomb sights. It can stay out all day without refueling and fly safely through fog.

Two types of blimps are being used by the Navy. The L-type can be operated by one pilot who has control of both the elevators and rudder. These are chiefly for instruction. The K-type patrol blimp carries a crew of 8 or 10 men as well as 6 homing pigeons, each in a separate cage. These are released to take messages to the base when the radio is silenced.

The bag on the K ship has a capacity of 416,000 cubic feet. The blimp is filled with noninflammable helium contained in a tough cotton fabric bag treated with synthetic rubber to prevent excessive diffusion of the gas. It is 250 feet long and 76 feet high, has a speed of 75 miles an hour, and a flight range of 2,000 miles. Duties other than spotting and destroying U-boats include location and marking of mine fields, rescue functions, protection of convoys, and the performance of scouting missions.

R. H. O.

Chlorinated Water Testing.—(*Scientific American*, Vol. 169, No. 5.) Testing water purified with calcium hypochloride for residual chlorine is simplified by a new method developed by the Quartermaster Corps in collaboration with the Medical Corps and several industrial chemical companies.

The testing method employs orthotolidine in a newly developed tablet form rather than in solution, each tablet representing one cubic centimeter of

the liquid. Orthotolidine, a chemical reagent that produces an intense yellow-green color in the presence of chlorine, is widely used for determining the extent of chlorination of water.

The tablets are packed in a nested double tube, the inner one of glass containing 50 tablets, and the outer one of plastic serving as a tube for the testing operation. The outer tube has a ¾ inch transparent yellow band at the top showing the exact color the water should have when tested after chlorine treatment.

In the testing operation, the outer tube is filled to the lower edge of the yellow band with the treated water and the tablets are dropped into it and allowed to dissolve. If the resulting color of the liquid in the tube is lighter than the color of the yellow band, the water requires more treatment with chlorine, while an equal or slightly darker color indicates the water has been satisfactorily purified and is safe for use. If the liquid turns an orange color, the water is too heavily treated with chlorine and more untreated water must be added to the supply being tested.

The new testing method was devised to replace the more complicated conventional method employing orthotolidine in liquid form.

R. H. O.

Starting Diesel Engines in Winter.—(*Diesel Power and Diesel Transportation*, Vol. 21, No. 10.) The U. S. Army now has a sure method of starting Diesel engines instantly, when the thermometer reads as low as − 40 deg. F. This real accomplishment is the result of a year's research on the part of the Texas Company at the request of the U. S. Army Ordnance Department.

Army specifications called for a method of starting engines instantly at − 40° F., and further stipulated that the accepted design must be able to operate for 24 hr. or more without attention, must not consume electrical energy, and must be adaptable to a wide variety of engines.

Engineers at Texaco's research laboratory made cold room studies and found that at "40 below" batteries were "dead"; motor oil had hardened to a plastic like material between pistons and cylinder walls; and starting, even by hand cranking, was all but impossible. Even if a start were made, it was pointed out that oil would not pump, bearings would burn out, and cylinder walls and pistons would score.

Why not, reasoned these engineers, use a small petroleum-burning stove to give continuous heat to the engine coolant and allow the coolant to circulate by thermosiphon action to the other parts of the engine requiring warmth? The scheme worked and the Perfection Stove Company was requested to build a tiny stove to certain specifications.

This stove burns only about a gallon of fuel in 24 hr. and the entire system is as much a part of the engine as an ordinary passenger car heater is of a vehicle. Cold room tests and field trials in northern Canada showed that starting an Army vehicle in sub-Arctic temperatures will be just as easy as starting the family car on a spring morning.

It is believed that this new device will have post war use on commercial vehicles parked for long periods without protection from the weather, and on motor trucks which operate on a stop-and-go schedule and thus cannot

reach the best operating temperature. Stationary Diesel engines on outdoor construction could also use such a device to great advantage.

R. H. O.

Special Addition Agent Steels.—R. B. SCHENCK. (*S.A.E. Journal*, Vol. 51, No. 11.) In a paper presented at the recent S.A.E. National Tractor Meeting, Mr. Schenk described the meaning of the term "special addition agent" as referring to a group of ferroalloys containing boron, which have the property of markedly increasing the hardenability of many steels when added in relatively small amounts.

The main reason for the interest shown in these materials is the promise they offer of conserving critical alloying elements. It now seems quite certain that, by suitable adjustment of steel chemistry, these alloys can be used to replace important amounts of such elements as nickel, chromium and molybdenum.

After giving some detail on the use of special addition agents, testing procedure and an exposition of results, the work was summarized, which showed the following: The additive treatment of steel from a commercial viewpoint is relatively new, having started in 1938. The general effect is to increase the hardenability and improve the mechanical properties of steel in the quenched and drawn state. In other than the quenched and drawn state, the mechanical properties are lowered, at least in some steels. The improvement in mechanical properties from the additive treatment is confined mostly to the carbon and low-alloy steels, and is most pronounced at draw temperatures of 300–500° F. In general, it may be stated that, with respect to hardenability and mechanical properties, a carbon steel can be made equivalent to a low-alloy steel and a low-alloy steel equivalent to a high-alloy steel by additive treatment. The addition agents may be added either in the ladle or ingot mold, preferably in the ladle. Ingot mold addition greatly facilitates experimental work. The amount of additive required varies, depending upon the type of additive, the composition of the steel and the degree of deoxidation. Uniform melting practice is essential to good results. In spite of the exacting requirements to be met in melting treated steels, a number of mills have demonstrated their ability to melt heat after heat with as good uniformity as untreated steels. No standard specifications now exist for special addition agent steels. It is obvious that chemistry alone will not suffice, and that hardenability and possibly mechanical properties must be specified in addition to chemistry.

R. H. O.

Drawing Chromium-Molybdenum Steel.—IRWIN H. SUCK. (*Steel*, Vol. 113, No. 18.) Deep drawing of hot rolled chromium-molybdenum steel, never considered well adapted for this purpose, has been mastered by Walter Kiddie & Co., New York, in large scale production of high pressure cylinders for carbon dioxide and oxygen.

The company is meeting the demand of the armed services for unprecedented numbers of cylinders, many of which are used for fire extinguishing equipment on aircraft, etc., for oxygen and for life raft inflation. The new

type of cylinder now in production for aviation use is made shatterproof from gun fire by a closely wound covering of piano wire.

The tough chromium-molybdenum steels are not normally considered of deep drawing quality, but it was necessary in this case to use a steel of this type to meet strength, weight and dimensional requirements for cylinders set up by the Interstate Commerce Commission and the armed services.

The cylinders must withstand test pressures of 3,000 pounds per square inch and service pressures up to 1800 pounds, and at the same time meet rigid weight specifications. Also they must be free from scratches and retain uniform wall thickness. On top of all this it was necessary to maintain volume production of some 30 sizes. These range in capacity from 8 to 2,000 cubic inches, in length from 7 to 50 inches and in diameter from 2 to 9 inches. No shells are drawn however, measuring over 7 inches in diameter and 28 inches in length, due to limitations of the press equipment.

In working out the manufacturing procedure, which principally involves drawing, cleaning, annealing and heat treating along with a minimum amount of machining, punches and dies proved to be one of the most difficult problems requiring solution. This and the problem of lubricants for the several drawing operations required considerable experiment.

The company buys S.A.E.-X4130 in flat sheets for the cylinders. Carbon range in this steel is 0.25 to 0.35 per cent.; chromium 0.80 to 1.10, manganese 0.40 to 0.60 and molybdenum 0.15 to 0.25 per cent. Circles are blanked out on a 500-ton single acting, double crank mechanical press. All subsequent cupping and drawing operations are performed on double and single action hydraulic presses, the number of draws (usually about six) depending on the size of the cylinders.

About 40 per cent. of the total reduction is achieved in the first cupping. Wall thickness tolerances are held to .005 inch in the sizing operation after the cylinder has been drawn to specified diameter and length.

Following each draw, the cylinders are cleaned with a chemical solvent in continuous washing machines and are then annealed at 1300 degrees Fahr.

R. H. O.

Magnesium.—R. H. RAMSEY. (*Chemical and Metallurgical Engineering*, Vol. 50, No. 10.) Southern Nevada at first glance appears to be populated at present largely by soldiers, faro dealers, and employees of Basic Magnesium, Inc. In fact B. M. I. takes up more space, is the subject of more gossip, has cost more money, and actually turns out more metal than any other one magnesium plant in the world.

Everything about B. M. I. is collossal. It uses all the peat moss Canada can supply, all the power Boulder Dam can spare, all the men it can get, all the electrical equipment three of our largest companies could manufacture, and it is still growing. B. M. I. at full capacity produces over twice as much volume of metal, measured in cubic feet, as one of our larger open-pit copper mines.

It must be admitted, however, that although both Canada and the United States produced some magnesium metal as far back as 1918, Germany has, until recently, led in magnesium production and technology, chiefly because magnesium is one of the very few metals Germany possesses within her borders.

Alloys of magnesium were used by the Germans in the first World War and were manufactured afterward.

In Southern Nevada, 31 miles from the railroad and 1,100 miles by rail from the reduction plant, is a concentration of almost pure magnesite (magnesium carbonate).

Ore sent to the mill must contain not more than 4 per cent. insoluble material, 4.5 per cent. CaO or 2 per cent. FeO and Al_2O_3. MgO content should be about 40 per cent.

Sequence of operations in B. M. I.'s main reduction plant is as follows: (1) calcined magnesite, mixed with coal and peat and suitably prepared, is heated in furnaces (called chlorinators) in an atmosphere of chlorine; (2) the anhydrous $MgCl_2$ formed in the chlorinators is transferred to electrolytic cells wherein molten magnesium collects in a pool on the electrolyte's surface; (3) dipped out of the cell by hand, the molten magnesium is then refined and cast into bars. In addition to these many units—the preparation plant, the chlorinators, the cell houses and the refining plant—the company also operates a chlorine plant, a flux preparation plant, a caustic soda plant, a brine plant, and a $MgCl_2$ liquor preparation plant, most of which are as large as any similar units operating elsewhere.

R. H. O.

Sabotaging the Saboteur.—(*Modern Plastics*, Vol. 21, No. 5.) With the safety of our most vital war zones and production centers dependent upon workers' identification cards and badges, the Air Plant Protection Branch at Wright Field recently took steps to insure that the passes to the plant are used only by those to whom they are issued and that they are impossible of duplication. These new tamperproof passes consist of cards bearing statistical information and photographs sealed between double layers of cellulose acetate which have been coated with a liquid adhesive. Attempts to rip one of these identification sheets apart will succeed only in splitting the paper into layers rather than in loosening the plastic. Such tampering will immediately catch the eye of the guards on the look-out for saboteurs.

As a further protection against enemy agents, invisible identification marks are applied to the cellulose acetate sheets. Since these ink markings are visible only under certain rays, even the employees do not know of their existence. Periodically when the passes are to be inspected, employees thrust their hands, holding the cards, through a hole in a partition. Beyond the wall, away from the workers' eyes, an inspector shines the special ray upon the passes, thus illuminating the design impregnated with the plastic. If the original photographs or signatures have been cut out and others substituted, breaks in the lines of the design will be evident.

In addition to being supplied to all Wright Field employees, these new forgery-proof identification passes are used by the Air Service Command at all Army Air Force fields and supply depots. The Coast Guard also is employing the system on cards issued to residents of restricted areas along both coasts. Thus, one by one, the possible loop holes for enemy spies and saboteurs are being plugged.

R. H. O.

Collection and Disposal of Magnesium Dust.—JOHN M. KANE. (*Heating and Ventilating*, Vol. 41, No. 1.) The greatly increased use of magnesium in the manufacture of parts for aircraft and other war products has brought attendant hazards of fire and explosion due to the extreme inflammability of the fine magnesium particles produced. Thus, a great deal of attention has been given to finding the best means of collecting and disposing of magnesium dust and chips to avoid the danger of their ignition.

When water is used as a collecting medium and the magnesium particles are stored in a flooded state, they cannot be ignited. Stored magnesium in a flooded state should not be confused with damp material which does ignite readily. In spite of the good experience with water, the use of a high flash point oil has been suggested as a collecting medium. A comparison of the characteristics of oil and water will indicate the respective advantages of each.

There is no reaction between oil and magnesium to liberate hydrogen. Any damp accumulations on collector surfaces stay oily and do not dry out. There is no critical mixture of oil and magnesium where the burning of magnesium is accelerated. Oil may provide better quenching to any burning particles carried to a dust collector. Collected particles removed from the collector are coated with oil and can be more safely stored and disposed.

On the other hand, considerable oil will be lost by entrainment and adherence to collected material representing added operating expense. Oil vapors in the exhaust air will probably prevent recirculation of the cleaned air. Supply of make-up oil and the use of satisfactory oil rely on the human element. Dust collectors cannot be easily drained to facilitate removal of collected material.

Excellent experience over an extended interval on a large number of unit type dust collectors employing water indicates that many of the advantages of oil are more theoretical than actual. The amount of hydrogen generated is diluted well below any hazardous concentration and is much lower than concentrations from pickling and anodizing tanks.

It is apparent that oil is a safe collecting medium, but with the limited experience in the field and with the extensive satisfactory experience where water has been used, it is premature to recommend it as superior to water for safe operation of dust collectors.

R. H. O.

The Use of Freon in Insecticides.—L. D. GOODHUE. (*Refrigerating Engineering*, Vol. 47, No. 1.) The Baltimore-Washington Section of the American Society of Refrigerating Engineers recently heard Mr. Goodhue on this subject in which he stated that a new method of applying insecticides which uses Freon as a solvent and propellant has been developed. This method gives improved results compared with those obtained with the oil-base insect sprays commonly used to combat household insects. It eliminates the oil and produces a floating fog that spreads to all parts of the enclosure and reaches every insect.

These floating suspensions are called insecticidal aerosols, since "aerosol" is the scientific term used to denote a smoke or fog. They can be prepared by several other methods, but the release of a solution of the insecticide in a liquefied gas through a small capillary or nozzle has proved the most satisfac-

tory. As the highly volatile solvent reaches the atmosphere, it boils violently and distributes the insecticide in the form of a fine suspension.

A very satisfactory aerosol is produced from a solution of pyrethrum extract and sesame oil in liquid dichlorodifluoromethane (Freon-12). It is a very effective insecticide against mosquitoes, which spread the dread diseases of malaria and yellow fever. It is also toxic to flies, ants, wasps, roaches, and many other insects. A container has been developed and accepted by the Army. Most of the solution is now packaged in these containers, which have a capacity of 1 lb. Because of their appearance they are called aerosol bombs.

The aerosol is especially well adapted for airplane fumigation to prevent the transport of disease-carrying mosquitoes and other insects. It meets the requirements of being nonpoisonous to man and animals, nonflammable, and requiring no extra spray equipment. It can be ready for use in a moment's notice. It can be used in barracks, tents, foxholes, and even in the open. Only 5 milligrams (one small drop) of the active principle, pyrethrin, in $\frac{1}{100}$ oz. of Freon is needed to kill all disease-carrying mosquitoes in 1000 cu. ft. of air.

R. H. O.

Titanium Pre-Dip Process Increases Life of Zinc Coatings.—(*Iron Age*, Vol. 153, No. 5.) Millions of dollars have been spent on paints, brushes and treatments to delay the inevitable rusting or oxidation of metals. Conspicuous success has been achieved by treating metal surfaces with phosphoric acid solutions to increase paint adhesion and thereby improve corrosion resistance.

Zinc remained stubborn and would not take the phosphate coating evenly. Early in this work a curious phenomenon was discovered by Westinghouse engineers. If the zinc surface is wiped with the hand, a brush or a cloth before it is treated, excellent phosphate coating results. Just why this happens is not altogether clear. Nevertheless many methods of wiping the zinc surface before treatment were attempted. In production, however, uniform wiping is difficult even on plain surfaces; on irregular objects it is impossible.

In manufacturing zinc plated frames for outdoor type watt hour meters this problem of preparing the zinc surface to take the secondary protective coating of paint became serious. A young Westinghouse chemist proposed doing the wiping chemically instead of mechanically. Countless dips were tried with indifferent and inconsistent results. One day disodium phosphate was tried, with excellent results that could be duplicated as long as that particular batch of phosphate lasted. With the exact lot of disodium phosphate the result was a failure, although ordinary chemical tests revealed no difference. Finally in desperation a more critical test was made and a faint trace of titanium—one part in a million—was found. Herein lay the answer. For some reason a mere whisper of titanium is the magic that makes the pre-dip solution of disodium phosphate work as a chemical wipe on zinc for subsequent and final phosphating treatment.

The process is now being applied extensively on a commercial scale for protection of hundreds of zinc coated machine parts for both war and peace. Certain war products receive a layer of zinc only 0.0003 in. thick. When given the titanium pre-dip and the normal phosphate coating they are able to meet

the 100 hr. salt spray test with ease. Without the titanium pre-dip, corrosion appears in an hour or two.

R. H. O.

Three Metals Plated Simultaneously.—(*Iron Age*, Vol. 153, No. 5.) Certain copper or brass parts of aircraft instruments that carry high frequency currents must have high surface conductivity because of high frequency skin effect. Nickel, normally used to provide anti-corrosion protection, has high electrical resistance. Gold plate, which is a good conductor, is too costly.

Electrochemists at Westinghouse finally evolved an answer that disposed of this particular worry and provided a plating technique valuable in many applications unrelated to the original need. Special plating anodes are made of an alloy of copper, tin and zinc. With these soluble anodes, copper and brass parts are plated using standard plating practices.

The results are more than satisfactory, according to Westinghouse engineers. The plated surface has the necessary electrical conductivity for high frequency applications and is far superior to nickel in corrosion resistance. Further, the finish is mirror-like, being surpassed in this respect only by silver itself. As to abrasion, the surface is roughly twice as good as the usual nickel coating. The new plating is entirely non-magnetic (not true for nickel) and is easily soldered, a fact of great value in many electrical applications. Furthermore, the new plating process has great "throwing power." In other words, deep interior surfaces (in objects with cavities) are plated much more uniformly than is possible with nickel.

R. H. O.

Cast-Off Hosiery Helps Wage War.—S. G. ROBERTS. (*Compressed Air Magazine*, Vol. 49, No. 1.) American women have been asked to forego silk and nylon stockings and to give the Government all such hosiery that has been laid aside because of "runs" or other defects. Willing as our women no doubt are to contribute in this manner, they, as well as other persons, may wonder how the adoption of stockings of other fabrics can help our fighting men to battle more effectively with our foes.

Up to the year 1904 smokeless powder, for use in large U. S. Navy guns, was packed in bags of bunting, the same thin woolen material that has been used for many years for all naval flags. An investigation disclosed that in addition to the high temperature gases lingering in the bore of a large gun after firing there were likely to be smoldering bits of bunting. Both the gases and the bunting contributed to a disaster in 1904 on one of our battleships by igniting bags of powder placed in the gun by the crew in reloading for the next shot. After considerable research, naval experts discovered that a fabric of natural silk was far superior to bunting because it would be consumed well-nigh instantly by the powder flames; and bags of raw silk have been in use ever since in our battle fleet. As a further safeguard against "flare-backs" the Navy devised means for discharging a strong blast of compressed air into the bore at the breech of a gun immediately after firing and before opening the breech.

This clears the weapon of hot gases and any residue from the inflamed powder bags.

No raw silk is produced in America, and, of course, war in the Pacific makes importation impossible. About 90 per cent. of the silk that was imported from Japan prior to the war was utilized to make women's stockings; and these are still our highest potential source for silk reclamation. Approximately fifteen pairs of stockings provide sufficient material to make one average sized powder bag.

Nylon likewise is a vital war material and its function in national defense is nearly as important as that of silk. Something like 90% of all nylon produced prior to Pearl Harbor went into stockings. By a method of reclamation it is possible to reduce the nylon in stockings to a state that permits both reworking and reconverting it at a considerable saving of time over the process of making new nylon as a product of chemistry.

The strength, lightness, elasticity, durability, and adaptability of nylon fits it for many essential wartime services. It serves, for instance, to make parachutes and parts such as tapes, shroud lines, harness webbing, belting etc.

R. H. O.

Current Zero Phenomena.—E. W. BOEHNE, a member of the Committee on Science and the Arts of The Franklin Institute and a General Electric switchgear engineer, recently read a paper before the AIEE discussing a method of determining the inter-relation of recovery voltage, arc current, and arc resistance variations. During the microsecond period in which an interrupter is performing the act of changing from a conductor to an insulator, Mr. Boehne explained, the current, voltage and arc resistance undergo variations which materially affect the performance characteristics of the interrupter. The nature of these variations depends upon the medium of interruption, design features of the interrupter, and the constants of the current and recovery voltage circuits. Modern power interrupters employing air present variations in the current zero region of an entirely different type from that observed in the liquid interrupters.

Interrupters which exhibit large arc voltages over the entire arcing period experience reduced recovery voltage oscillations and have the additional advantage of operating in a region which permits the current to be diverted and approach zero at a rate slower than normal.

Conversely, interrupters which develop low arc voltages are, in general, capable of producing greater than normal rates of change of current in the current zero region. Hence, under conditions of small inductive currents in circuits of high natural frequencies, this action leads to overvoltage conditions which must be considered in their application.

The rapidly varying resistances within the interrupter during the process of interruption have always presented obstacles to the analyst. In reapproaching this problem on the basis of an orderly, yet practical, variation of circuit current in the region of current zero and allowing the parameter of resistance to become secondary, the problem reduces to one of linear constants and can be solved by standard methods.

Mr. Boehne's paper presented such a treatment. It is generalized in such a way as to include all practical types of current zero phenomena generally encountered. Recovery voltage characteristics are literally fabricated from "standard building blocks" of which relatively few are required. The method is flexible enough to be applied to any assumed current variation in the region of current zero. The analysis is presented in terms of the accepted nomenclature of circuit theory. The operational attack is used.

R. H. O.

V.2
194